BASIC FIRE CONTROL MECHANISMS: MAINTENANCE

DEPARTMENT OF THE NAVY BUREAU OF ORDNANCE

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RESTRICTED

ORDNANCE PAMPHLET 1140A

BASIC FIRE CONTROL MECHANISMS - MAINTENANCE

1. Ordnance Pamphlet 1140A describes procedures for the diagnosis of casualties, disassembly, repair, reassembly and bench checking of basic fire control mechanisms. This book supplements OP 1140 which explains the theory of operation of these basic mechanisms.

2. This publication is a basic text and reference manual providing a source of specific information for the maintenance of basic fire control mechanisms. It is intended that the study of OP 1140A will be a prerequisite for the study of Ordnance Pamphlets on the maintenance of fire control equipment.

3. This pamphlet does not supersede any existing publication. Ordnance Pamphlet 1140, Basic Fire Control Mechanisms, should be consulted for details of operation of the mechanisms.

4. This publication is RESTRICTED, and shall be safeguarded in accordance with the security provisions of U.S. Navy Regulations, 1920, Article 76.

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INTRODUCTION

Scope and purpose of OP 1140A

Maintenance of Basic Mechanisms, OP 1140A, was prepared to serve a dual purpose: It is both a textbook and a reference manual. Whichever way it is used, a thorough knowledge of *Basic Fire Control Mechanisms,* OP 1140, is assumed.

The novice may use OP 1140A as a primer to help him develop the skill and experience necessary for successful trouble shooting and repair of the typical basic mechanisms common to the various computing instruments. The skilled fire controlman may use OP 1140A as a guide to actual trouble shooting, disassembling, repairing, and reassembling the units for combat, where experience, skill, care, and precision finally pay off.

The various mechanisms described in OP 1140A are representative of the types of units used in the equipment. Although each unit described is actually in use in one of the major instruments in the fire control system, they are not all to be found in any single installation. Because of different features of design in the various instruments, units which are basically alike may not be identical in construction. Careful study of the typical unit, however, should lay a solid foundation for successful maintenance and repair of other units of the same type.

As a reference manual used on board ship, OP 1140A is a companion to the equipment OP's, and should be consulted only after a test analysis and unit checks as described in an equipment OP have clearly indicated that a particular basic mechanism is not functioning properly. Only mechanisms which have been disconnected from all associated units are discussed in this manual.

Removal and repair of units

If it is determined that a unit must be removed for repair, the instrument OP should always be consulted for instructions. Moreover, study of the instrument OP and OP 1140A should be supplemented by careful reference to the instrument schematic and gearing diagrams as well as the assembly drawings of the particular unit.

Beyond this, the fire controlman should always double check while the unit is still in place to make sure of the exact source of the trouble before attempting to remove any unit. This double checking is especially important because many of the units are very difficult to remove from the instruments. The actual repair job may take only a relatively short time compared with the time required to remove the unit.

As a general rule, a faulty unit or part should be replaced rather than repaired, if a replacement is available. The cause of the casualty should always be found and eliminated before the instrument is put into operation after a unit has been repaired or replaced. Otherwise the same casualty may occur again.

Estimated time on a repair job should also be carefully weighed against the possibility that the *actual time* required may be much greater. Superficial inspection may indicate only a minor repair job, yet when the unit is removed and disassembled, unforeseen repairs or replacements may be necessary. Only the responsible fire controlman can decide whether a particular repair job can be done in the time available, or whether it should be undertaken at all. Especially in combat areas, an expedient measure may be adopted instead of a more desirable repair operation. Sometimes damage which is relatively serious within a given unit may not actually affect the final computation very seriously. If the time available to make the repair is short, it may be decided to postpone the job until it is safe to secure the fire control system. In each situation, many factors must be taken into account, and all such decisions are governed by *ship's doctrine*.

Skill and precision

Modern fire control instruments are built with the fine precision traditionally associated with watchmaking. Outwardly a computer appears to be a very rugged piece of gear, and it is. But most of the working parts are machined to tolerances ranging from 0.002 to 0.0002 inch, and the surfaces of mating parts are polished to almost a mirror finish. It is obvious that skill and extreme care are required for repair operations on this equipment.

Anyone who attempts to disassemble, repair, and reassemble the basic mechanism in these instruments, especially in preparation for combat, should have a sound knowledge of basic machine shop practices. Ideally, the work should be undertaken only by a skilled fire control mechanic. In many situations, of course, experienced personnel are not available. With this in mind, OP 1140A was written so that it may be used as a guide for the less experienced. In an emergency, however, it may be advisable for an inexperienced fire controlman to call on a machinist's mate for help on machine work.

Special tools and skills

Trouble shooting and repair can often be simplified somewhat if special tools and fixtures are improvised to do particular jobs. OP 1140A gives directions for making some of the most useful of them. But because of the complexity of the instruments and the difficulty of forecasting exactly what casualties may occur, it is impossible to know just what special tools and fixtures should be at hand. The equipment of the machine shop on board ship may sometimes be used to supplement the tools in the computer tool kit.

A good deal of information about the skill and know-how developed over many years in the shops of the manufacturer is included at the end of this introduction under the heading of *Manufacturer's Practices.* This information should be very useful, but it is not intended to give specific instructions for doing any particular repair job, nor to establish any sort of doctrine.

GENERAL PLAN OF OP 1140A

The material in this manual is arranged to progress from the relatively simple to the more complex units. Since it will be used as a guide to trouble shooting and repair on board ship, the number of cross references has been held to a minimum by repeating some information in chapters where it is essential to the operations described. The subject matter is presented in five main divisions:

Part 1. Basic Tools and Operations

Part 2. Non-computing Mechanisms

Part 3. Computing Mechanisms

Part 4. Electromechanical Mechanisms

Part 5. Lubrication

It is essential that anyone using this manual be thoroughly familiar with the contents of Part 1.

Part 1. Basic Tools and Operations

Part 1 includes a presentation of the necessary tools for repairing basic mechanisms, instructions for making certain special tools and fixtures, and a detailed explanation of the essential basic repair operations on shaft assemblies. The term *shaft assembly* has been used to indicate the basic unit making up a *shaft line*. Since a large proportion of the required repairs in fire control instruments are done on shaft lines, the explanation of shaft assembly repairs is of fundamental importance.

Part 2. Non-computing Mechanisms

Part 2 is concerned with shaft lines and the various relatively simple mechanisms which are used as parts of shaft lines or in connection with them. This part of OP 1140A includes chapters on shaft lines, shaft line devices, handcranks, dial assemblies and counters, and the intermittent drive.

Part 3. Computing Mechanisms

Part 3 deals with all the basic mechanisms which actually solve the mathematical problems involved in the general fire control problem. There are chapters on the bevel-gear and jewel differentials, multipliers, component solvers and vector solvers, disk and ball integrators, the ballistic computer, and computing cams.

Part 4. Electromechanical Mechanisms

Part 4 deals with non-computing units which involve both mechanical and electrical problems. It presents chapters on wiring, push-buttons and switches, the follow-up, servo and synchro motors, synchro receivers and transmitters, time mechanisms, and the solenoid units.

Part 5. Lubrication

Lubrication is one of the most important of all maintenance procedures, of course. This final part of OP 1140A defines the proper lubricants and explains the approved methods of applying them to basic mechanisms. The information is a detailed supplement to the general instructions given in each chapter for the lubrication required in reassembling the unit.

HOW TO USE OP 1140A

OP 1140A will be much more immediately useful to the fire control mechanic who acquaints himself with the basic structure and function of the chapters in the book. A typical chapter has seven main division headings, including the chapter title, which is the name of the unit. As a rule of thumb, the unit names are ordinarily those used in OP 1140, *Basic Fire Control Mechanisms.*

Basic plan of chapters in OP 1140A

The seven main division headings of a typical chapter are as follows:

Chapter title (unit name)

Typical symptoms

Locating the cause

Dissassembling the unit

Repairing the parts

Reassembling the unit

Bench checking the unit

All these main divisions are closely related to each other, especially *Typical symptoms, Locating the cause, Disassembling the unit,* and *Repairing the parts.* For this reason, the entire chapter should be read before any disassembly or repair operation is begun, if time permits.

Chapter title (unit name)

This section introduces the fire controlman to the unit and gives him various necessary cautions. It provides a general description of the unit, the locations of the inputs and outputs, and the way the unit is mounted in the instrument.

Typical symptoms

This section gives the mechanic a bird's-eye view of the symptoms which he can check and observe without disassembling the unit. After he has correctly identified the symptom, he should turn to the proper subdivision under *Locating the cause* for help in diagnosing the trouble and prescribing treatment.

Typical symptoms consists primarily of definitions of the main symptoms of mechanical trouble, in terms of each particular unit: jamming, sticking, excessive lost motion, and slipping. These symptoms vary somewhat from unit to unit, and the electromechanical units have symptoms of electrical trouble in addition.

JAMMING means that one or more parts which should move cannot be moved by normal force, usually hand pressure. A jammed or frozen part may prevent the movement of other parts in the same unit which are not directly jammed themselves. Usually some play can be detected in a part which is held by jamming of some other part of the mechanism.

STICKING means that one or more parts move sluggishly throughout their normal travel, or resist moving past certain points where they bind or almost jam. A sticking part may jam eventually if the cause is not eliminated.

EXCESSIVE LOST MOTION means that there is too much play between sliding or otherwise mating parts which are fitted to close tolerances.

SLIPPING means that a part which should be mechanically held is free to move.

The names of the typical symptoms, usually combined with the names of particular parts, are repeated as subtitles under *Locating the cause.*

Locating the cause

Having identified the symptom, the fire controlman can use this section to help him diagnose the specific cause of the trouble in terms of pins, gears, and shafts, without unnecessary disassembly of the unit.

Under subtitles which include the names of the symptoms, there are detailed discussions of the possible causes of each one. The first sentence of each subdivision names the causes in the order in which they are discussed, and the explanation is based on the best method of checking.

Once the cause has been located, the operator will know whether the unit must be disassembled to make the repair, and he can turn to *Disassembling the unit* or *Repairing the parts*, or both.

Disassembling the unit

If the unit must be disassembled for repair, the operator will turn to this section for a reliable disassembly procedure. It is a list of steps in chronological order for the complete disassembly of the unit. Sometimes only a part of it may be used, depending on the particular repair job.

Repairing the parts

In this section, the repair man will find detailed explanations of the main repair operations prescribed in *Locating the cause*. This section does not present rigid step-by-step procedures, but offers full discussions which appeal to good judgment by suggesting alternatives and giving reasons and cautions.

Reassembling the unit

Here the mechanic will find a reliable procedure for reassembling the entire unit. It is a list of numbered steps in chronological order, introduced by an important explanation of the necessary cleaning and lubrication of all the parts as they are reassembled.

Bench checking the unit

This final section enables the fire controlman to make sure that the unit is completely ready to be reinstalled in the instrument. It presents a numbered list of essential steps and conditions.

MANUFACTURER'S PRACTICES

Here are descriptions of several maintenance operations and a number of inspection requirements which have been developed in the shops of the manufacturer of these instruments and followed successfully for many years. The descriptions offered here should be found helpful, but they are not intended to establish any sort of doctrine.

The material is presented under the following headings:

WASHING AND CLEANING OPERATIONS

There are many possible ways of washing and cleaning the basic mechanisms discussed in this OP, but some are preferable to others. Descriptions are given here of the manufacturer's methods of washing mechanical units and ball bearings, and of removing rust-preventive coatings from replacement parts.

Washing mechanical units

A suitable solvent for washing and cleaning mechanical units is Deo-base, included in the lubrication kit supplied by the manufacturer. Water-white kerosene which meets the Navy Specification 14K1 is equivalent to Deo-base. Freezene Medium Refrigerating Oil, also included in the lubrication kit, is often mixed with the solvent, 1 part in 100, to provide a protective film on metal surfaces after the solvent evaporates. This oil is a white mineral oil.

A jet spray in an especially equipped booth is often used for washing and drying operations. The booth and its accessories are designed to expel the solvent vapors so as to prevent their being inhaled by the operator; to filter dirt and chips from the solvent; and finally, to blow the excess solvent from the cleaned units with clean, *dry* compressed air.

It has been found desirable for the operator to hold the mechanisms with hooks or tongs, because the jet spray may cause skin infections if it is directed against bare hands. Chips of metal or foreign material may pierce the skin, and the solvent itself may penetrate too far into the pores.

Because of possible damage to painted surfaces, they are never subjected to the jet spray treatment.

Mechanical units may also be cleaned by the method used for washing ball bearings.

Washing ball bearings

Ball bearings and sometimes other parts of mechanical units are washed by direct immersion in the solvent. A bearing may be placed in a sieve and cleaned by agitating the sieve in the cleaning agent, or it may be dipped in the solution and turned by hand.

Dirty bearings are turned slowly to avoid possible damage to the balls and races which may be caused by spinning them too fast.

Removing rust-preventive coatings

A replacement part is immersed in a container of the solvent and allowed to stand until the heavy rust-preventive coating is completely dissolved. Then the part is rinsed in another container of fresh, clean solvent, dried thoroughly, and lubricated before it is installed.

RUNNING-IN AND FINAL FITTING OPERATIONS

Slight sticking or roughness of mating parts which are fitted to close tolerances is sometimes eliminated by lubricating and running the parts together for a short time. If running-in the parts with a lubricant does not make them operate smoothly enough, a running-in compound may be used. One compound is used for running in soft metals, and another for hardened steels.

The purpose of the running-in operation is only to remove *minor* surface imperfections on gear teeth, slide blocks, slides, and other parts which slide, roll, or in some way bear upon each other. It is essentially a polishing operation. Burrs and nicks which can be seen or felt are removed with a fine oilstone before running-in is even considered.

For running in parts made of soft metals such as aluminum, brass, bronze, and unhardened steel, 230-mesh screened rottenstone is used as the running-in agent in the compound. For running in parts made of hardened steel, pumice stone is used as the running-in agent.

A running-in compound mixed as follows has been found satisfactory:

Parts by Volume	Navy Specification
2 Petrolatum	14P1
1 DTE Light Oil	
3 { 230-mesh rottenstone for soft metals; or pumice stone for hardened steel only	

The compound is made by heating the petrolatum to about 170° Fahrenheit, adding the light oil, and then slowly adding the rottenstone or pumice stone. By vigorous stirring, the powder is smoothly and uniformly distributed throughout the compound.

The running-in compound is applied uniformly and very sparingly to the surfaces to be smoothed. The parts are then run together for a short time, slowly. Gears in particular are not run in at speeds high enough to cause the compound to be thrown off into bearings or other mechanisms. After the running-in operation is completed, every trace of the compound is washed from the unit, because if it is not completely removed, it may cause excessive and uneven wear or possible damage to some of the parts, *especially the bearings.* Finally, the unit is completely lubricated.

CEMENTING OPERATIONS

Two cementing procedures used by the manufacturer are described here: cementing *cork to metal,* and cementing *rubber* or *neoprene* gaskets.

Cementing cork to metal

Cementing cork to metal involves cleaning the surfaces of the cork and the metal, applying the adhesive to both parts, pressing them together at the right time, and finally, clamping the parts and baking them. The materials used are adhesive and cleaning agents.

The adhesive is a pure orange shellac, an 8-pound cut of the type included in the lubrication kit supplied by the manufacturer. It meets Federal Specification TT-V-91a, Type 11 Orange, Grade A. Thinned adhesive is made by diluting one volume of the shellac with two to three volumes of denatured alcohol which meets Federal Specification TT-V-91.

The cleaning agents are trichlorethylene, lacquer thinner, or gasoline. The trichlorethylene meets Navy Specification S1T3; the lacquer thinner meets Federal Specification TT-T-266; the gasoline is a commercial white gasoline which contains *no* tetraethyl lead.

The *metal* surface is cleaned with trichlorethylene, lacquer thinner, or gasoline. Then it is air-dried and wiped clean with a cloth dampened with alcohol. Either of two methods is used to clean the *cork* surface: It may be wiped with a cloth dampened with lacquer thinner or gasoline, and then allowed to dry thoroughly; or if the surface is dry, it may be roughened with a fine file and the dust and particles air-blown away.

A coat of thinned adhesive is applied to both the cork and the metal surfaces, and they are air-dried for fifteen minutes.

A coat of pure orange shellac is then applied to the cork. The cork is immediately pressed firmly and evenly against the prepared surface of the metal. Considerable care is required to obtain a good bond, free of air bubbles.

In preparation for baking, the cork is covered with parchment paper to prevent its sticking to the clamp. The cemented parts are then clamped together and baked at 275° Fahrenheit for four hours or at 300° for three hours.

Cementing gaskets

Cementing a rubber or neoprene gasket to a metal cover is an operation similar to cementing cork to metal, but it is simpler because fewer steps and materials are required.

The adhesive used by the manufacturer for *neoprene* gaskets is No. 1 Fairprene cement. It becomes tacky in 30 minutes to one hour after it is applied. If it becomes too thick, it is usually thinned with trichlorethylene.

The adhesive used for *rubber* gaskets is No. 1201 Red Glyptal. It becomes tacky in 5 to 15 minutes after application. If necessary, it is thinned with No. 1500 GE thinner. Both materials are included in the lubrication kit supplied by the manufacturer.

Before the scarfed ends of a gasket are cemented together, they are cleaned with trichlorethylene. When they are dry, a coat of adhesive is applied to each scarfed end and they are then air-dried until the adhesive becomes quite tacky. Finally, the ends are pressed firmly and evenly together.

When a neoprene or rubber gasket is cemented to a metal cover, a coat of the proper adhesive is applied to both the gasket and the groove. The adhesive is air-dried until it becomes tacky, usually 30 minutes to one hour. Then the gasket is pressed into the groove very carefully to keep it from twisting. Any excess adhesive is wiped away with a cloth dampened with solvent. Finally, the cover is bolted to the instrument case so that the gasket is held firmly in place.

ASSEMBLY AND INSPECTION REQUIREMENTS

It is the accepted practice in the shops of the manufacturer to consult the assembly drawings of every particular unit for special information applying to that unit. Several general practices are followed, however, unless the assembly drawings specify a variation.

General tolerances and practices

Clearance between unrelated moving parts is not less than 0.008 inch.

Cotter pins are locked.

Shims are never used unless an assembly drawing specifies them.

Dowel holes are drilled when the mating parts are in their exact relative positions. The holes are perpendicular to the joining surfaces, and they are fitted so as to allow the parts to be separated and rejoined.

In *screw-driven mechanisms,* the screw turns freely but the total end play of the part moved and the screw shaft does not exceed 0.0015 inch.

The lost motion of a cam on a center pivot does not exceed 0.0005 inch.

The lost motion between a cam and a carriage in the direction of the carriage travel does not exceed 0.001 inch.

An *eccentric adjustment stud* is staked to hold it in position after an adjustment has been made. In staking a stud, a center-punch mark is made in the metal part where the stud is mounted, 1/32 inch from the edge of the stud and in line with the center of the slot. The effect of staking is to force a small amount of metal into the stud slot.

Flat-head screws are staked in the same way as eccentric studs except where the head is tightened against a hardened steel surface or a plate less than 3/32 inch thick.

Steel cap screws are lubricated with W. S. 511 grease before they are screwed into aluminum or steel. This grease is included in the lubrication kit.

Aluminum screws used in aluminum parts are lubricated with the anti-seize compound which is included in the lubrication kit. The compound is applied only to male threads, and it is carefully kept away from neoprene, rubber, or other plastic gaskets which it may damage by chemical action.

Shaft assemblies

A *spacer* is considered satisfactory when it properly fills the space where it is used. An additional, or extra spacer is never used. If a spacer is too thin, it is replaced; if it is too thick, it is filed down to the proper size.

A *taper pin* is set with the large end 0.005 to 0.01 inch below the surface of the hub, to provide room for staking. The small end is set within 0.01 inch above or below the surface of the hub. Where the hub must be smooth so that another part may turn on it, as in a friction assembly, for example, both ends of the pin must be below the surface. Every taper pin is driven in tightly and staked.

Adjustable or split hubs: A film of Freezene medium refrigerating oil is applied to the shaft and hub before the clamp is mounted. Before the screw is tightened, the clamp fits snugly on the hub and the hub turns freely on the shaft. After the screw is tightened, the clamp holds the hub firmly on the shaft without closing completely.

Computer mechanism gearing

End play, lost motion, and run-out of shafts and gears are kept within the following limits, measured with a dial indicator:

End play of shafts with straight-tooth spur gears: 0.0005 to 0.003 inch.

End play of shafts having one or more bevel, worm, or helical gears: 0.001 inch maximum.

Lost motion at gear meshes of spur, bevel, worm, and helical gears averages no more than 0.001 inch, and does not exceed 0.002 inch at any one mesh.

Run-out is measured by means of a dial indicator mounted with the point against the part in question. The limits apply to the total variation of indicator readings during one revolution.

A spur gear does not wobble more than 0.002 inch.

Bevel-gear eccentricity and wobble does not exceed 0.001 inch. This measurement is made with a dial indicator held perpendicular against the heel of the gear, near the root line of the teeth.

Synchro-receiver shaft assemblies run freely without apparent end play, lost motion, or run-out.

Component solvers

The travel of the racks is limited only by the cam groove or the lead screws.

Nothing interferes with the turning of the vector gear through 360°, regardless of the position of the pivot, except the stop pins, or, in some screw-type component solvers, the screw-input shaft hangers.

The center of the pivot passes through the axis of vector gear rotation within $\pm$ 0.001 inch.

Rack slots are at right angles to each other within 0.002 inch total variation of indicator readings throughout the travel of each rack.

Disk integrators

Balls, disks, and rollers are free from dents, nicks, pits, scratches, soft spots, and all other surface imperfections.

The force necessary to move the carriage through its full travel does not exceed 1/2 ounce when the disk is horizontal and the roller is raised.

The disk is firmly clamped to the gear.

The clearance between the carriage balls and guide rollers does not exceed 0.0005 inch.

The side play of the carriage within the rails does not exceed 0.001 inch.

The clearance between the gear and the ball-bearing ring on the bottom of the gear does not exceed 0.001 inch.

The disks run in a plane parallel to the axis of the roller within 0.005 inch. This measurement is made with a dial indicator against one of the roller bearings. When the disk is turned and the carriage moved through its entire travel, the total indicator readings do not vary more than 0.010 inch.

Cam type multipliers

The travel of the parts driven by the cam is limited only by the cam groove.

The cam is concentric with its pivot within 0.001 inch, measured on the outside diameter.

Screw type multipliers

When the traveling blocks are displaced one inch from the fixed pivot, the lost motion between the input and output racks does not exceed 0.003 inch.

TOOLS and MATERIALS

Every repair man should have on hand the measuring instruments, hand tools, and bench equipment pictured on the following pages. In this OP, the explanations of instrument maintenance are based on the assumption that this equipment is available to the repair man and that he understands how to use it.

Not all this equipment will be required for any one instrument repair job, but the chapter on basic repair operations will show that many of them are used even on a simple job.

12-INCH STRAIGHT EDGE AND SCALE

6-INCH STEEL SCALE

6-INCH SQUARE

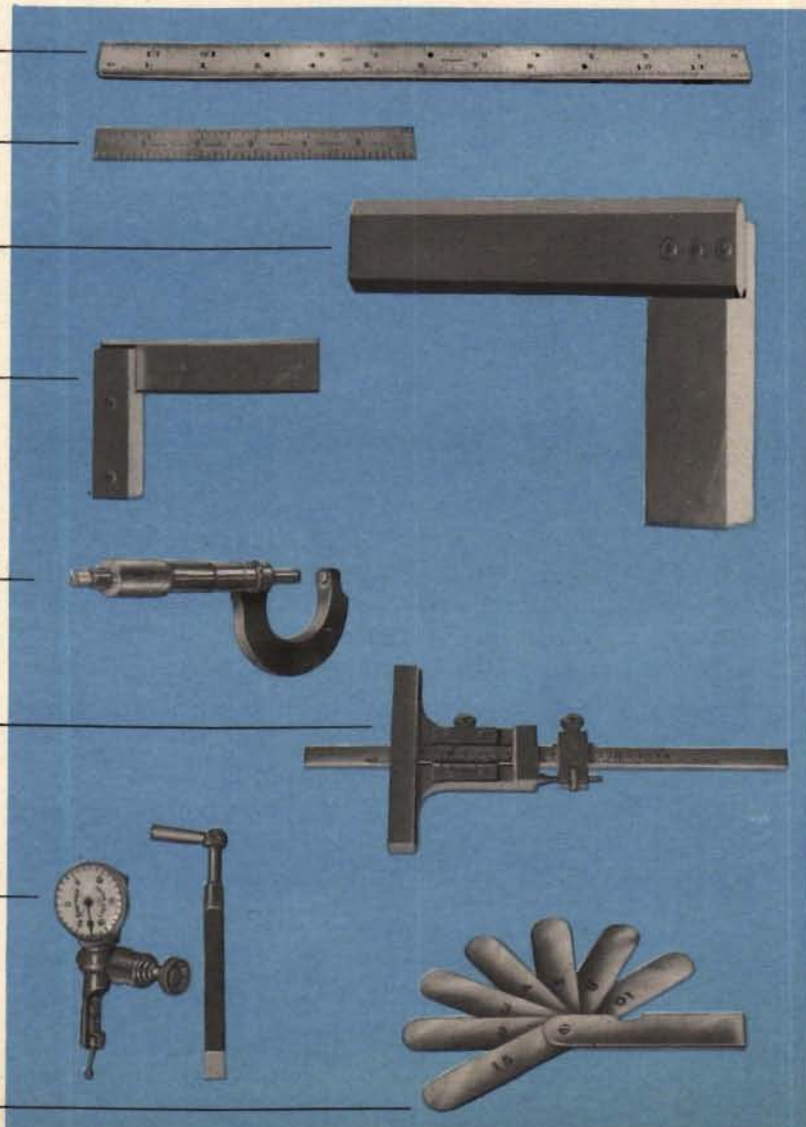
3-INCH SQUARE

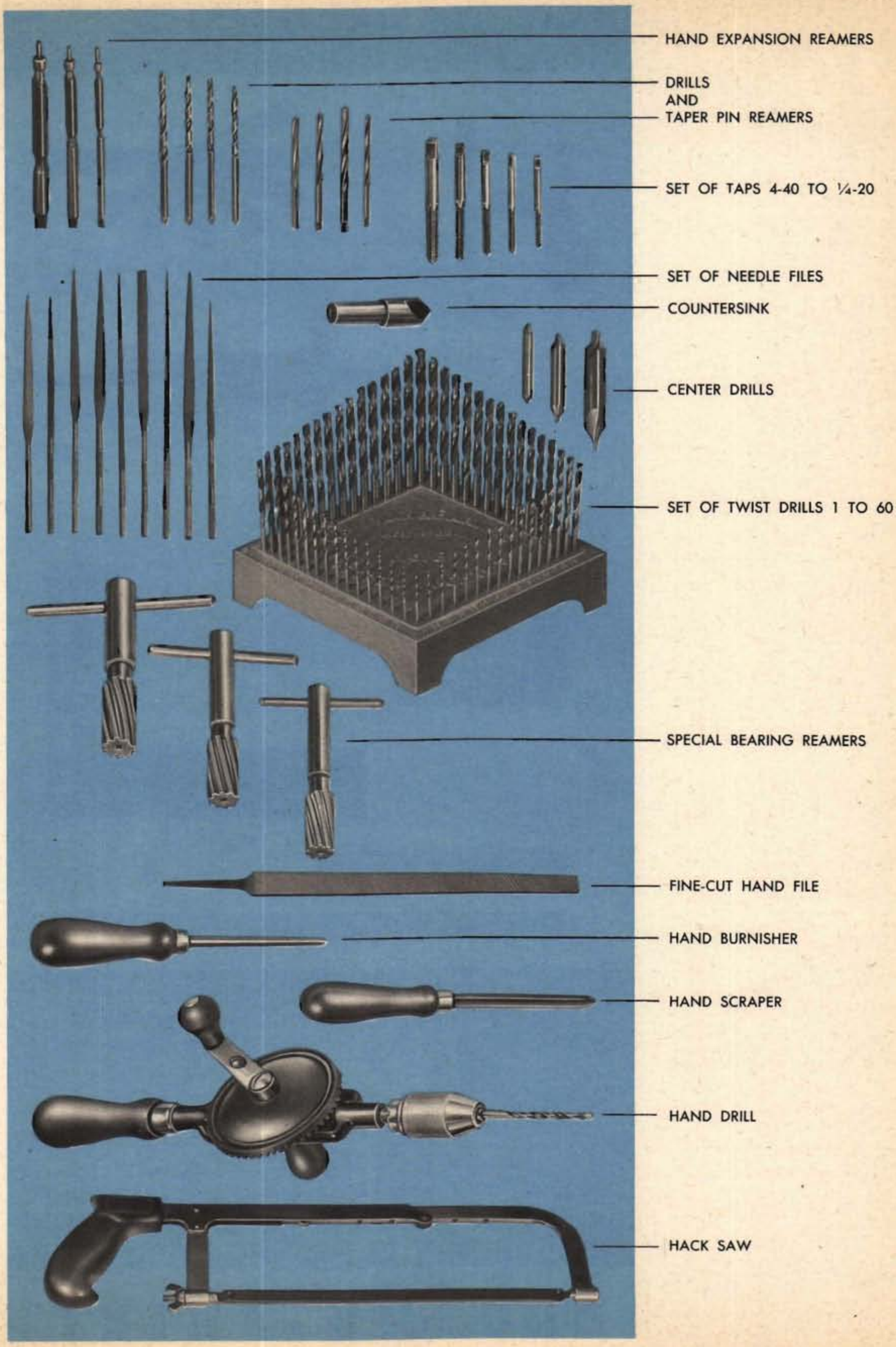
1-INCH MICROMETER

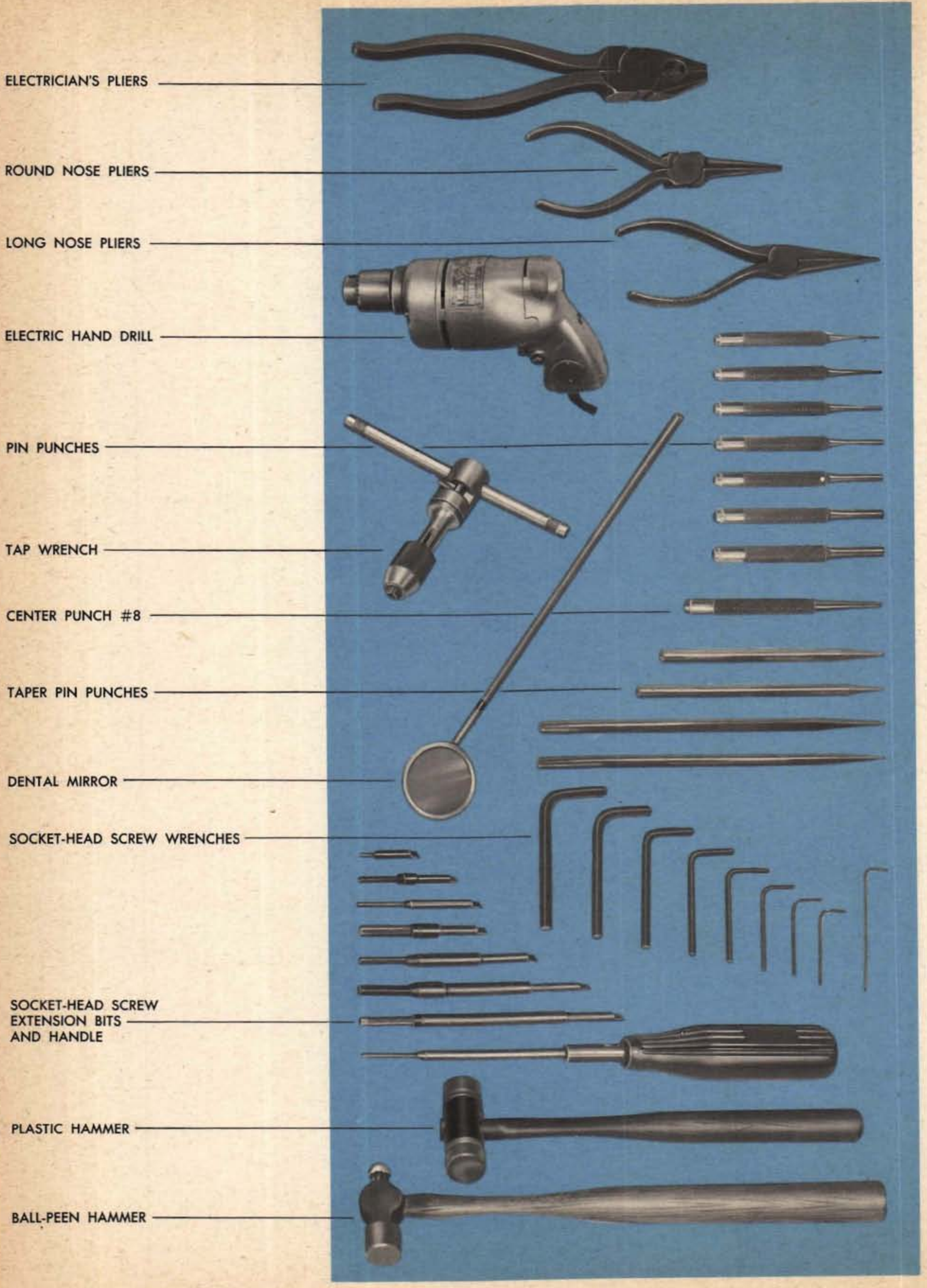
VERNIER DEPTH GAGE

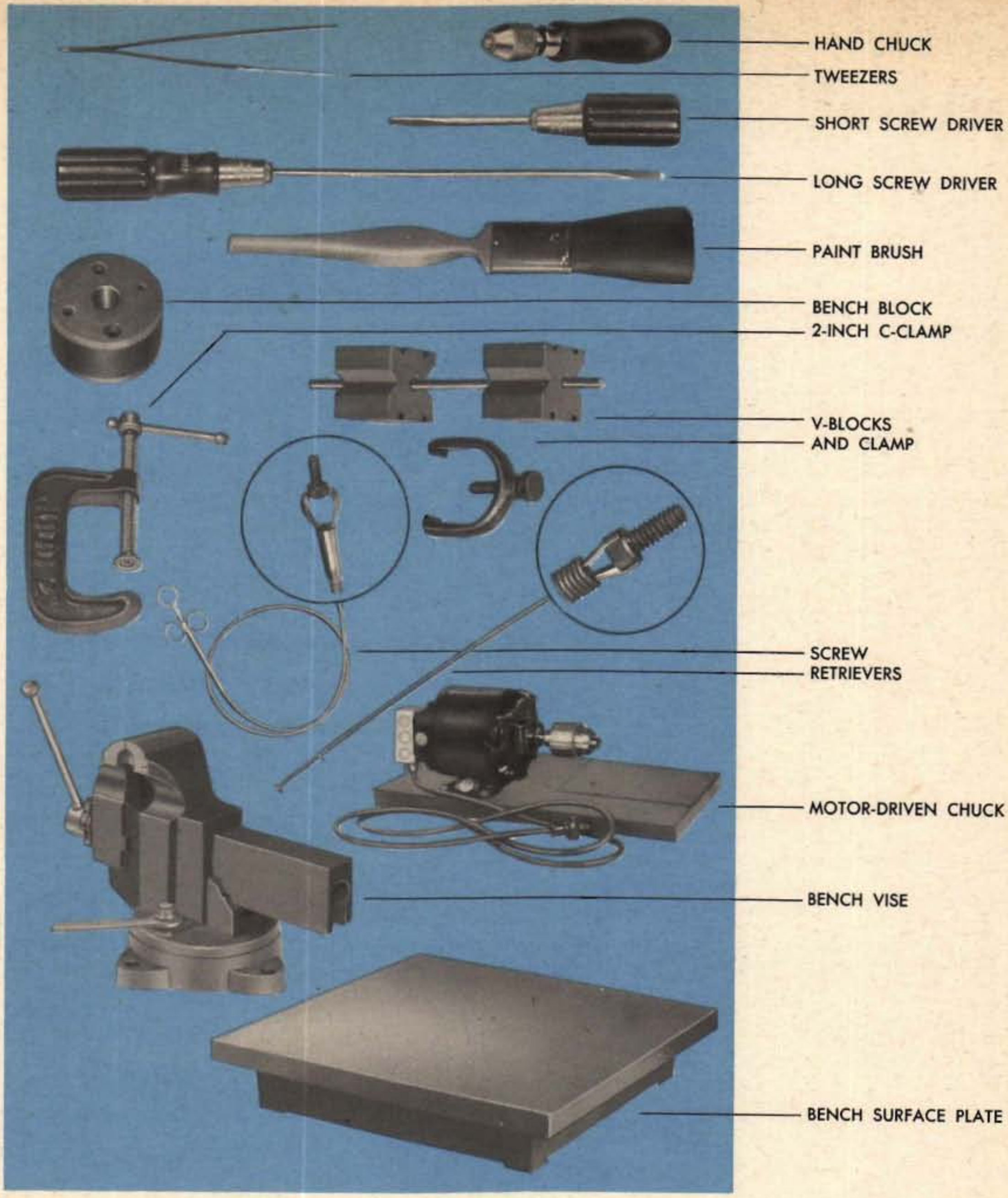
DIAL INDICATOR, UNIVERSAL TYPE

FEELER GAGE




HAND EXPANSION REAMERS
DRILLS
AND
TAPER PIN REAMERS
SET OF TAPS 4-40 TO ¼-20
SET OF NEEDLE FILES
COUNTERSINK
CENTER DRILLS
SET OF TWIST DRILLS 1 TO 60
SPECIAL BEARING REAMERS
FINE-CUT HAND FILE
HAND BURNISHER
HAND SCRAPER
HAND DRILL
HACK SAW


ELECTRICIAN'S PLIERS
ROUND NOSE PLIERS
LONG NOSE PLIERS
ELECTRIC HAND DRILL
PIN PUNCHES
TAP WRENCH
CENTER PUNCH #8
TAPER PIN PUNCHES
DENTAL MIRROR
SOCKET-HEAD SCREW WRENCHES
SOCKET-HEAD SCREW EXTENSION BITS AND HANDLE
PLASTIC HAMMER
BALL-PEEN HAMMER



Materials

In addition to this equipment, the following materials are required for instrument repair work:

- A suitable cleaning solvent.
- A light machine oil.
- Grease conforming to Army and Navy Aeronautical Spec. AN-G-3.
- Crocus cloth, very fine sandpaper, and an oilstone.
- An assortment of set screws, taper pins, soft iron wire, scrap metal rods, bakelite, etc.
- Some cheesecloth and a quantity of lint-free rags.

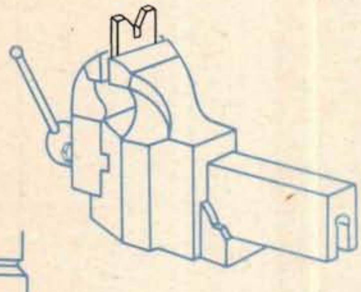
MAKING SPECIAL TOOLS AND FIXTURES

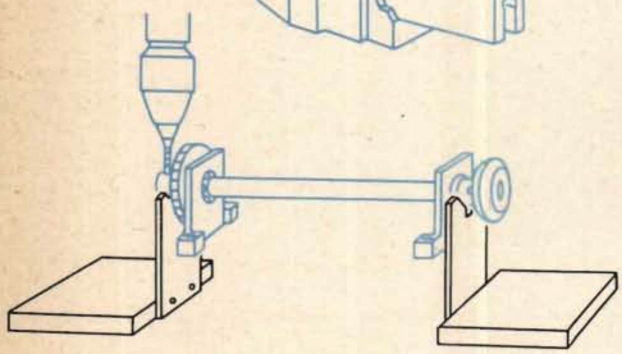
A few easily-made tools and fixtures will simplify all shaft-assembly repair in an instrument, and making them will give the trouble shooter a practical introduction to the tools and materials in his kit. Instructions follow for making these tools and fixtures:

Pinning supports	A bearing punch	Pin removers
Back-up tools	A support for seating and removing bearings	An inside knurling tool
A back-up bar		Snap ring tools
A hook support	A spacer filing fixture	A socket-head screw remover

The instructions given here for making these tools are meant to be general, so that they can be applied to different situations. All dimensions should be considered only approximate, and if a specified material is not available, a substitute will serve the purpose.

SIMPLE PINNING SUPPORT



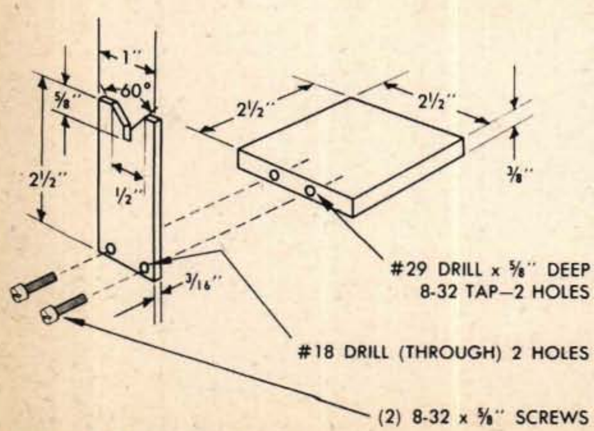


PINNING STANDS IN USE

Pinning supports

A simple pinning support to be held in a vise can be made of a flat strip of metal with a 60° notch cut in one end. This type of support is suitable for small repair jobs involving only a few shaft assemblies.

It is more convenient to have a *pair of pinning stands* as supports on the bench for shafts when they are checked for run-out or straightened, and for gears when they are drilled and pinned. For drilling and pinning operations, one of the stands is always placed directly under the hole or part to be worked on.



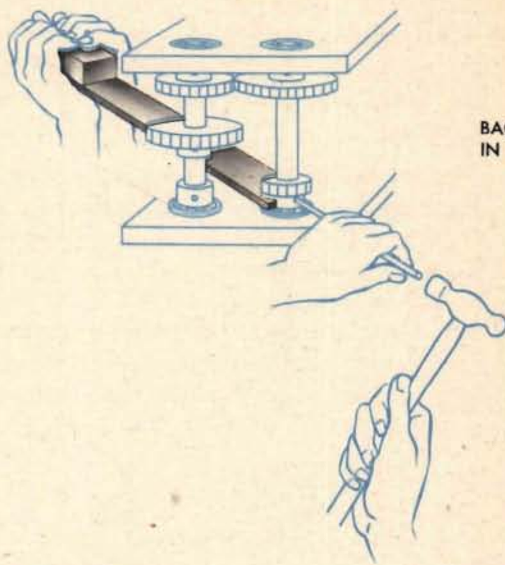
THE PARTS OF A PINNING STAND

MATERIALS: For the uprights, two strips of brass 2½" by 1" by 3/16" are needed, and for the bases, two steel blocks 2½" by 2½" by 3/8". Four screws 8-32 by 5/8" fasten the uprights to the bases.

Use a hack saw to cut a notch in the top of each upright to receive the parts when the stands are in use. First cut a V to form an angle of 60 degrees. Then cut a 1/8" slot in the bottom of the V, 5/8" deep measured from the top of the upright.

Back-up tools

Back-up tools are needed to support collars and hubs for pinning whenever parts must be pinned inside a large gearing group. A back-up bar is used when the part to be pinned can be reached from both sides, and a hook support when it can be reached from only one side. Two men are required for pinning when back-up tools are used.

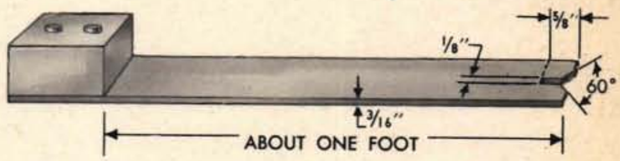


BACK-UP BAR IN USE

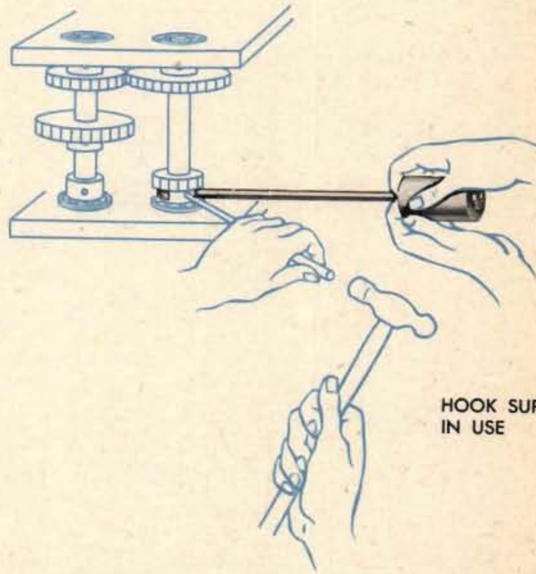
BACK-UP BAR

MATERIALS: The main element is a steel bar about 12″ long, 1″ wide, and 3/16″ thick. A steel or lead weight is attached to one end of this bar to absorb shock.

Make a notch in one end of the bar as described for the pinning-stand uprights. The weight may be screwed, riveted, or cast onto the other end of the bar.



BACK-UP BAR



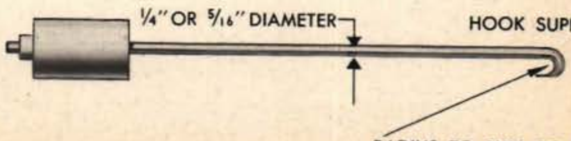
HOOK SUPPORT IN USE

HOOK SUPPORT

MATERIALS: The main element is a 1/4″ or 5/16″ steel rod at least 12″ long. A metal weight is attached to one end to absorb shock.

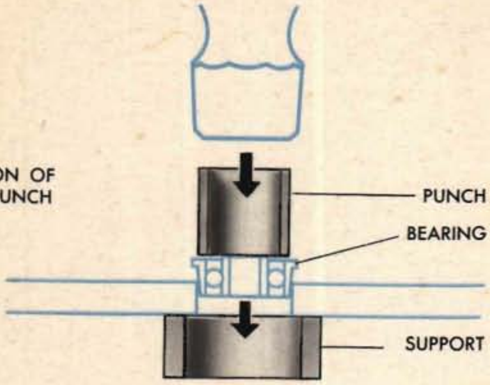
Forge a smooth hook on one end of the rod to fit the collars and gears to be held. During the forging operation, reduce the diameter of the rod at the hook end to about 3/16″ to enable the hook to enter narrow spaces easily. Then file the tip flat on the outside.

Fasten the weight to the other end of the rod as described for the back-up bar.

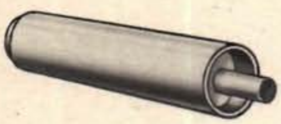


HOOK SUPPORT

CROSS-SECTION OF A BEARING PUNCH IN USE



A PILOTED PUNCH

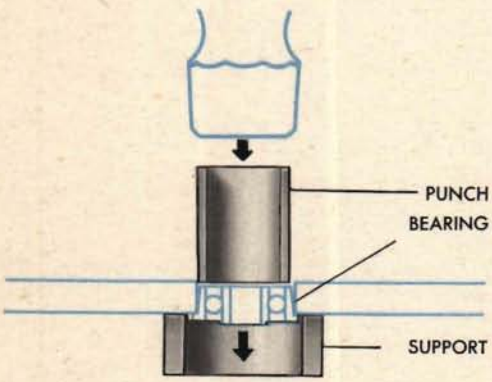


Bearing punch

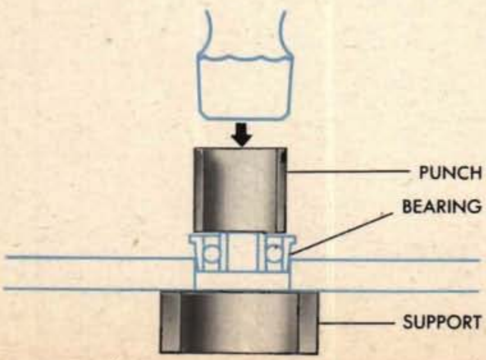
A bearing punch is needed to distribute and equalize the force of the hammer blows when bearings are removed or seated. For most repair work, all that is needed for a punch is a short, square-cut length of tubing about 0.005 inch smaller in outside diameter than the bearing hole. This tube must fit *inside the bearing hole and on the outer race* of the bearing.

For production work, a punch with a pilot to center it will save time. The pilot fits through the shaft hole, and the outer lip on the punch fits inside the bearing hole and on the outer bearing-race. A punch of this type can be turned on a lathe from a solid steel bar.

REMOVING A BEARING



SEATING A BEARING



Support for seating and removing bearings

A support must be used under a hanger or a plate to prevent its being bent when a bearing is removed or seated. All that is needed for a support is a square-cut piece of tubing large enough in diameter to fit around outside the bearing, and long enough to support the part conveniently on the bench.

Spacer filing fixture

In a shaft assembly, spacers are washers, or metal tubes of different lengths and diameters, which are fitted between the parts to hold them in their proper positions. In thickness or length, they vary from a few thousandths of an inch to several inches. The correct spacer length is determined by measuring the distance between the parts, or by the trial-and-error method of filing the spacer until it exactly fits its place in the assembly.

In all shaft-assembly repair work, spacers must be filed to the exact length, with the ends parallel and square with the bore. A spacer may be held in the hand and filed, but a spacer filing fixture simplifies this important filing operation.

MATERIALS: For the base, a steel plate 6″ by 2″ by ⅜″ is needed, and for the posts, three steel rods 3/16″, 1/4″, and 5/16″ in diameter and 1½″ long.

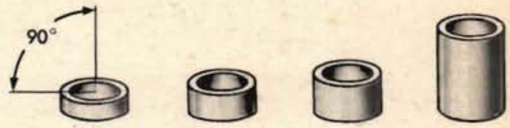
Drill three holes through the center of the base to receive the posts and ream them for a drive-fit.

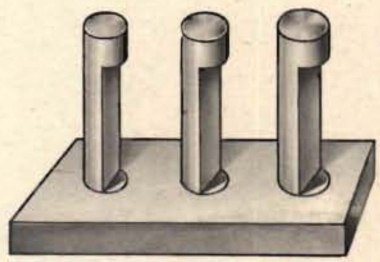
File each post on one side until there is a broad, flat surface to within ⅜″ of each end. To assemble the fixture, carefully drive the finished posts into the holes in the base.

TO FILE A SPACER, slide it over the post of the proper diameter. Use a fine-cut hand file, with smooth edges which will not file the post. It is important to keep the file parallel to the base, so that the file turns the spacer on the post and files the end square. Guide the smooth edge of the file along the flat side of the post. Using light but steady pressure, file the end of the spacer with long, even strokes.

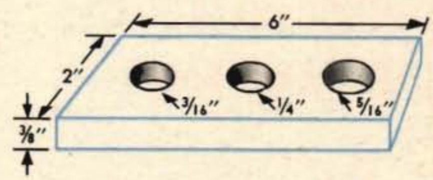
Before trying a filed spacer on the assembly, carefully remove all filing burrs and metal particles. Finally, measure it with a micrometer to be sure that the ends are parallel.

SPACER ENDS MUST BE PARALLEL AND SQUARE

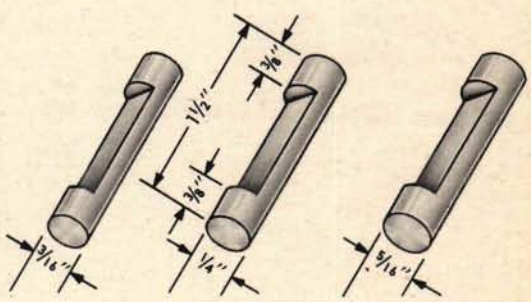




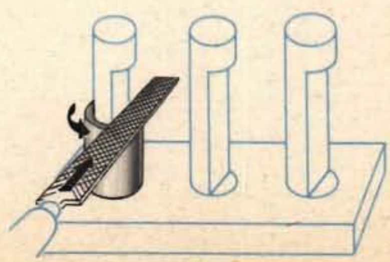
COMPLETED FILING FIXTURE



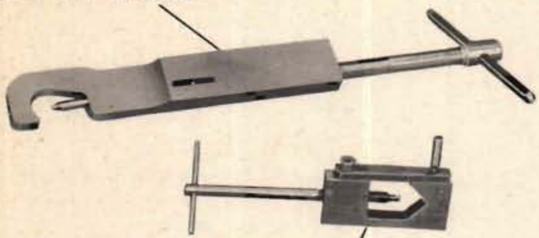
BASE

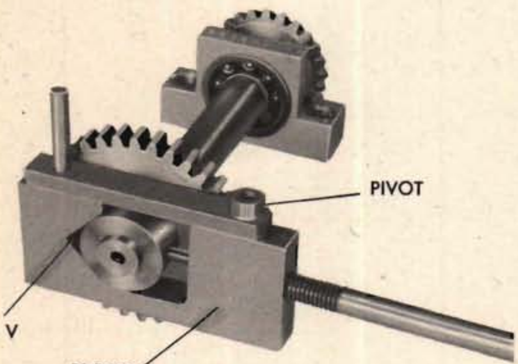


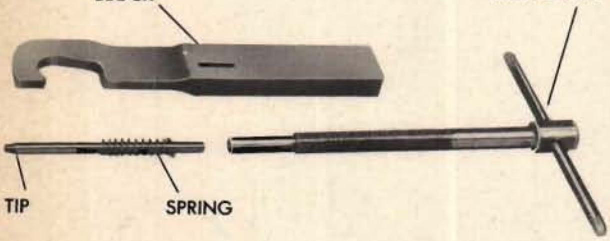
POSTS



FILING A SPACER







Pin removers

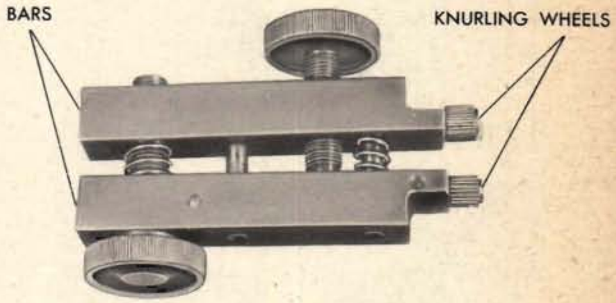
A pin remover is a special tool which may be used in place of the punch, hammer, and back-up tool combination. It greatly lessens the danger of bending a shaft and permits one-man operation.

The smaller of the tools illustrated is made from scrap tool steel. The block measures 2″ by 7/8″ by 1/4″. A hole or slot at the bottom of the V allows the pin to pass through. The pivoted bar over the jaw takes up any strain on the open side. The jack-screw, of 3/16″ diameter stock, is turned down at one end to fit the taper pins generally used. It is helpful to cup the end. A simple handle affords leverage.

The larger tool is more difficult to make, but it has several advantages over the smaller one. The punch end, or tip, does not turn with the jack-screw. This prevents "walking" away from the taper pin. With this tool it is possible to use several sizes of tips, including one for staking. The block for the tool illustrated measured 6″ by 1″ by 7/16″ before machining. The jack-screw is machined from a 6″ length of 1/2″ diameter rod. The tip is shaped from a length of 1/8″ rod.

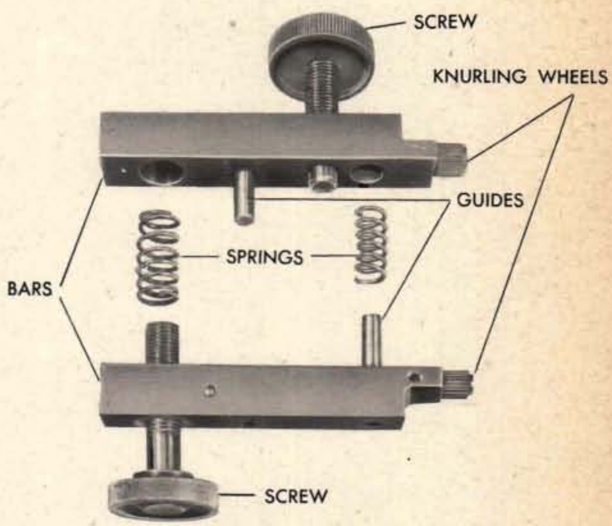
It is preferable to harden all the parts of these tools. If tool steel of the proper size and shape is not available, however, almost any steel will serve for all parts except the tip.

An inside knurling tool



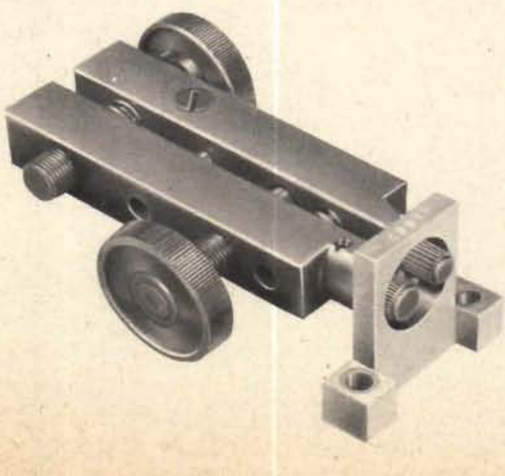
Except in emergencies, it is not advisable to reduce the diameter of a bearing hole in a hanger or plate. When an emergency arises, however, knurling is probably the best method. It is a means of making a temporary tight fit without a great deal of machining or preparation of intricate shims.

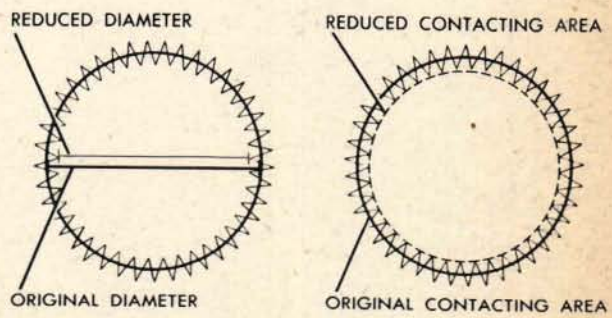
The tool illustrated cannot be bought. It is simply a mechanic's idea of a handy gadget to have in the tool drawer.



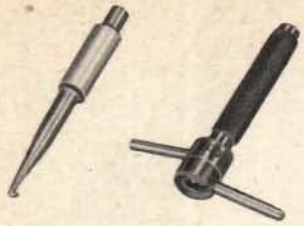
An inside knurling tool is somewhat like a parallel clamp except that the action of the bars is to spread rather than close. A knurling wheel on a stud is mounted at the working end of each bar. These wheels must be free to turn on the studs. Both the studs and the wheels are made from tool steel and hardened.

By forming a series of teeth on the inside surface of the hole, the effective diameter is reduced, but at the same time the contacting area is greatly decreased.



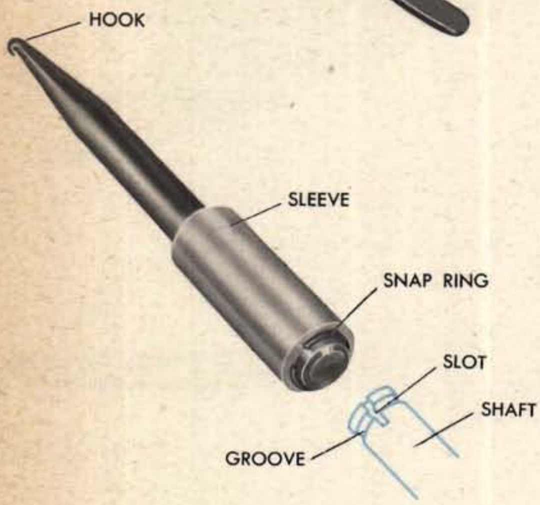


Snap ring tools



The tools shown here are designed to facilitate the installation or removal of the various types of snap rings.

With the proper tool, the handling of snap rings is quite simple. Without the tool, it is often difficult and usually results in damaged shafts, scratched parts, lost rings, and sometimes personal injury.



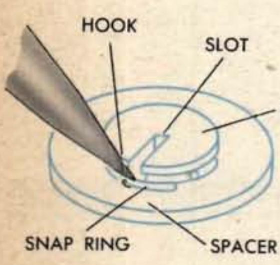
Several types of snap rings have been developed to meet the particular requirements of various intricate mechanisms. In repairing the mechanisms described in this OP, three types of snap rings will be encountered:

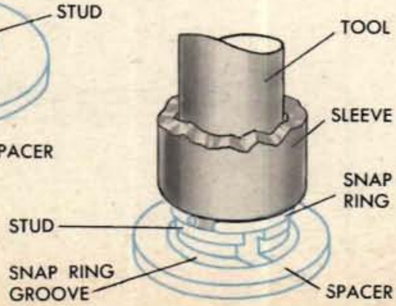
The circular cross-section snap ring, with a small gap.

The square cross-section snap ring, with a large gap.

The square or rectangular cross-section snap ring, fitted with eyes in flanges to accommodate a special installation tool.

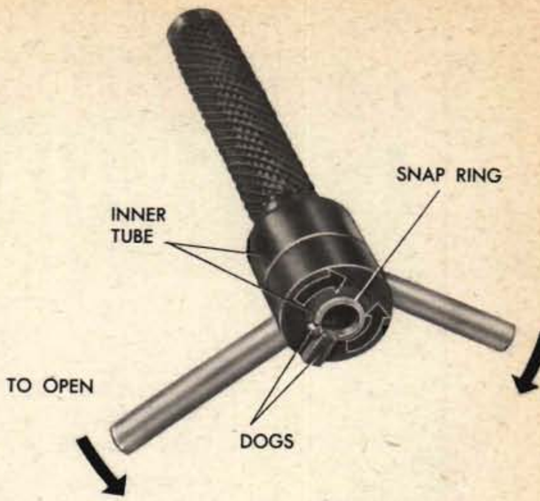
REMOVING AND INSTALLING A SNAP RING WITH A CIRCULAR CROSS-SECTION AND A SMALL GAP





To remove the ring, slip the hooked end of the tool under the ring at the recess made by the slot in the shaft. Pull the ring off. To install a ring, slide the ring on the tool, following with the sleeve. Set the rod against the shaft and transfer the ring to the shaft by means of the sleeve.

REMOVING AND INSTALLING A SNAP RING WITH A SQUARE CROSS-SECTION AND A LARGE GAP



To remove the ring, close the dogs by turning the handle of the inner tube counterclockwise. This positions the handles at about ninety degrees. Slip the tool over the shaft extension with the dogs inside the ring gap. Squeeze the handles to force the dogs apart and open the gap in the ring. This tool was designed for removing rings, but with careful handling it can also be used for installing them.

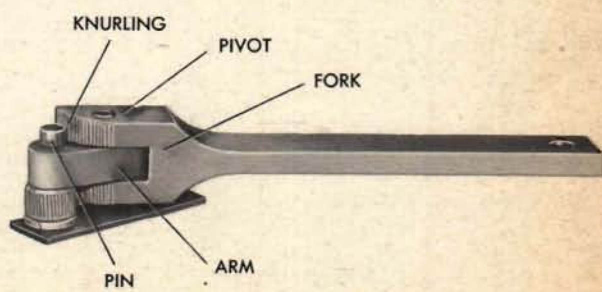
REMOVING AND INSTALLING THE SPECIAL TYPE OF SNAP RING

This is a commercial tool, supplied by the manufacturer of these rings. The method of using this tool is obvious.

Socket-head screw remover

This is a special tool for removing socket-head screws in which the hexagon socket has been mutilated.

The principle is the same as that of the tool for removing studs. It functions like an offset pipe wrench, adapted to a socket-head screw.



An arm with a pin through it pivots in a fork. The fork is knurled at the contacting surfaces. This type of tool is made from tool steel and hardened.

BASIC REPAIR OPERATIONS

SHAFT ASSEMBLIES

Generally in fire control instruments, quantities are transmitted by shafts and gears. Several kinds of shaft assemblies, which may be connected in many ways, are used to make up instrument shafting and gearing. For this reason, a basic knowledge of shaft assemblies is required for maintenance of these instruments.

This chapter is mainly an explanation of basic repair operations on shaft assemblies considered as mechanical units. Sometimes a shaft assembly must be treated not as an entirely independent unit, but in its connections with other units in an instrument. In general, however, basic repair operations are understood to include all those operations which may be necessary for the repair of any shaft assembly taken as a unit.

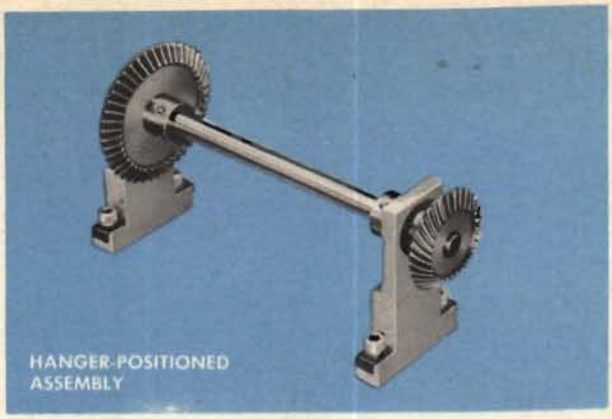
Some familiarity with the tools and materials described in the previous chapter is assumed.

Maintaining proper operation of a fire control instrument often requires moving a gear, installing a longer spacer, filing a collar or spacer, or repositioning an entire shaft assembly by moving the hangers. Maintenance may also require replacing a shaft or gear, or even rebuilding an entire assembly.

All repair of shaft assemblies is carried out in seven main steps:

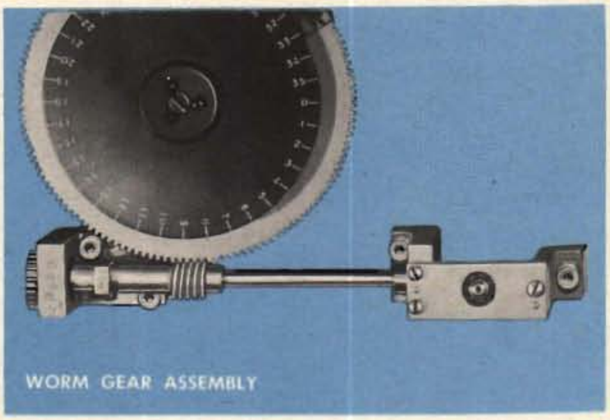
1. Removal and disassembly
2. Preparing the parts
3. Fitting the parts
4. Positioning the assembly on a plate
5. Pinning the parts
6. Bench checking the assembly
7. Final mounting of the assembly

The steps of this procedure must be followed just as carefully when only one part is repositioned or replaced as when an entire shaft assembly is rebuilt.

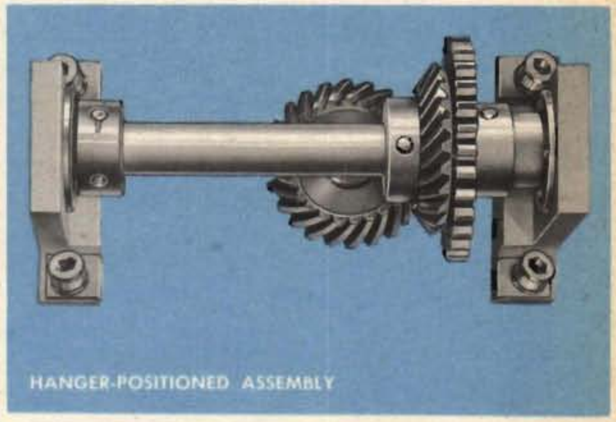


HANGER-POSITIONED ASSEMBLY

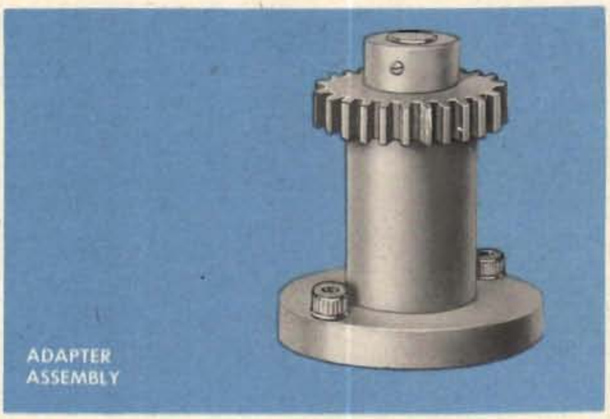
HANGER-POSITIONED ASSEMBLY WITH A CLAMP GEAR



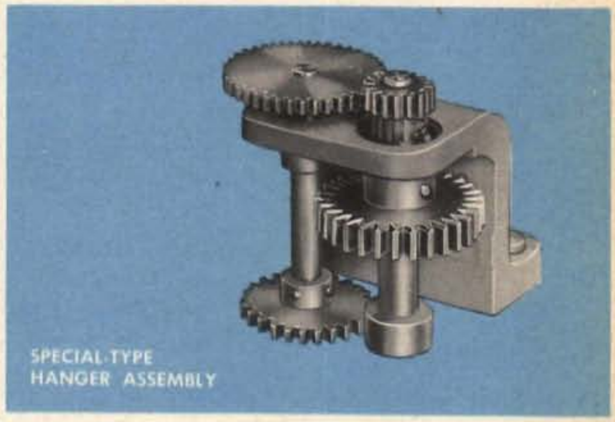
WORM GEAR ASSEMBLY



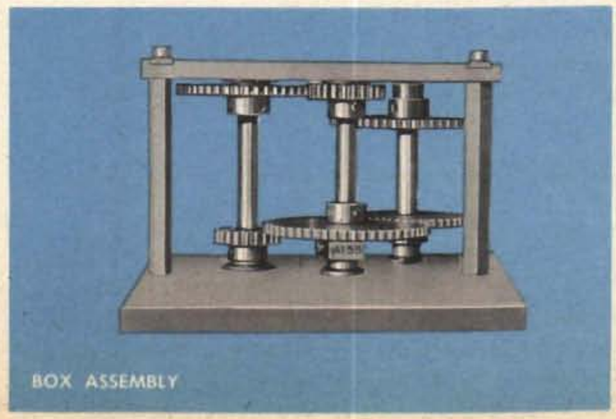
HANGER-POSITIONED ASSEMBLY



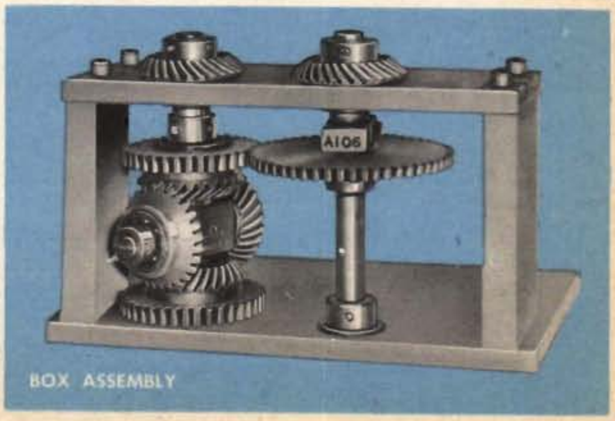
ADAPTER ASSEMBLY



SPECIAL-TYPE HANGER ASSEMBLY



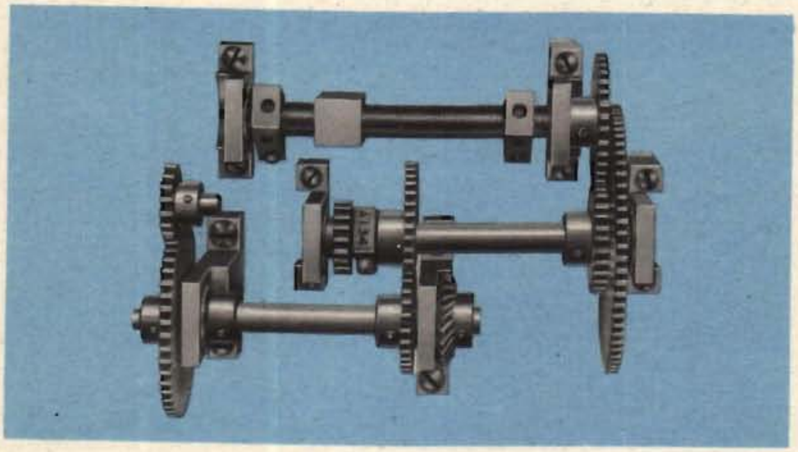
BOX ASSEMBLY



BOX ASSEMBLY

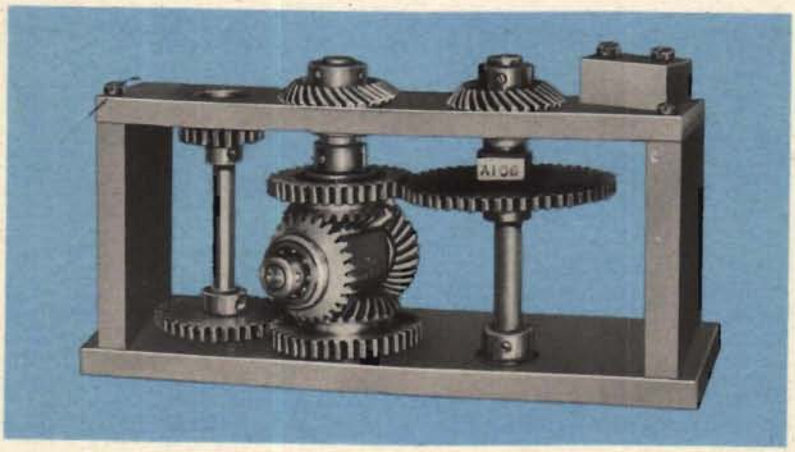
Removal and disassembly

Shaft assemblies are usually mounted either on plates or between the plates of a box assembly.



SHAFT ASSEMBLIES ON A PLATE

Those mounted on plates are positioned by screw-fastened hangers.



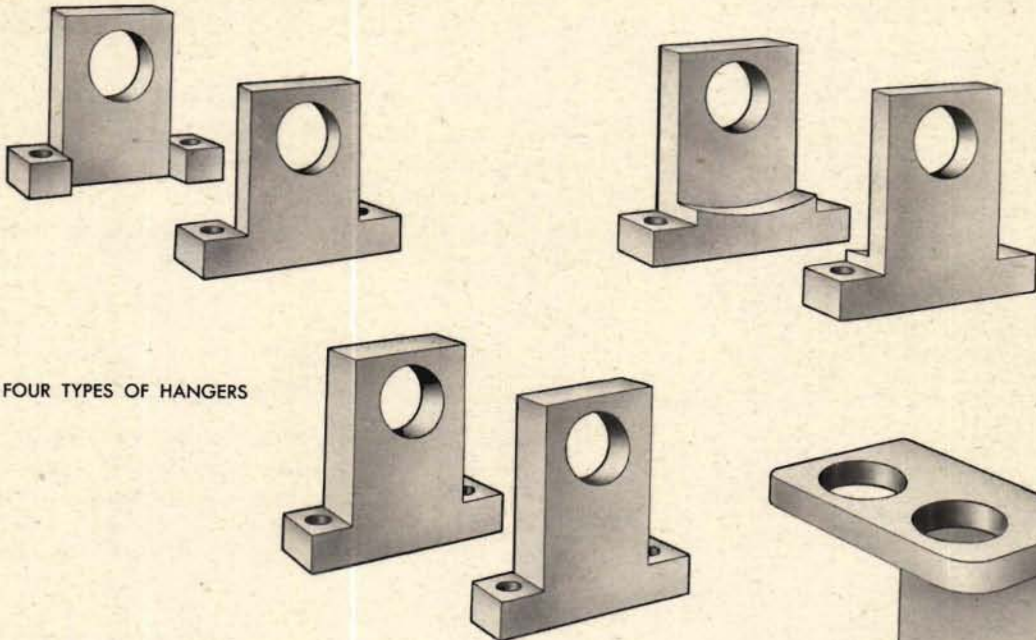
SHAFT ASSEMBLIES BETWEEN PLATES

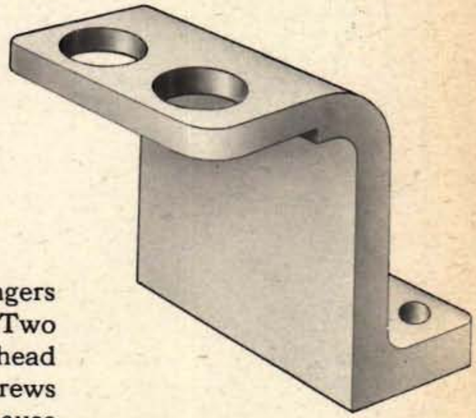
Those mounted between plates are positioned by the plates themselves, which are secured by screws but held in position by dowels.

Some plates are supported by posts to which they are fastened by screws.

Shaft assemblies are precision mechanisms, made up of light parts machined and fitted to close tolerances. All removal and disassembly operations must be carried out with great care in order to avoid damage to any of the parts. Always use the lightest tools and the least physical force that will do the job.

Removing hanger-positioned assemblies



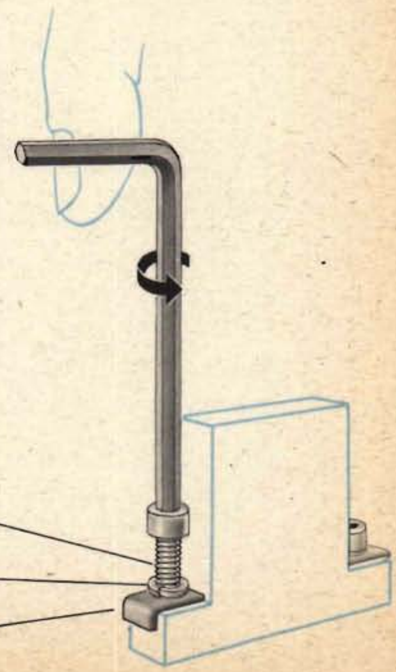


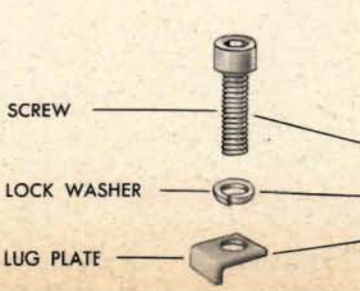
FOUR TYPES OF HANGERS

Hanger-positioned shaft assemblies are mounted on hangers which are fastened with screws to plates in an instrument. Two types of screws are used: slot-head screws and socket-head screws. During removal it is important not to drop any screws or other small parts into the instrument where they may cause a great deal of damage to other assemblies or mechanisms.

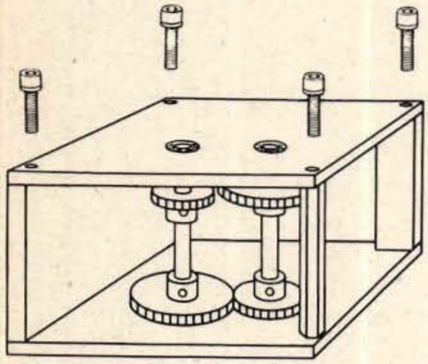
Remove the screws, lock washers, and lug washers or lug plates, and be careful to place them on the bench in separate groups with each screw to avoid interchanging any of the parts during reinstallation. Because the screws are often of different lengths, replacing them in the same holes is of critical importance.

Before attempting to lift out an assembly, check to be sure that no screw has been overlooked and left in place. Unless all the screws are loosened and removed, the assembly may be unnecessarily damaged.



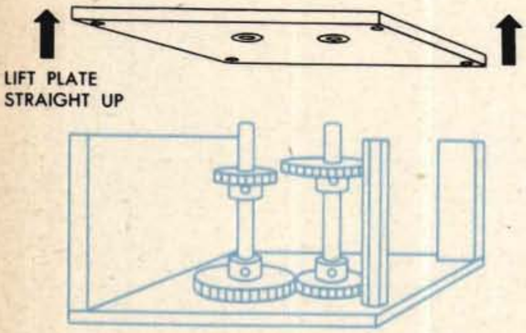


Removing plate-positioned assemblies

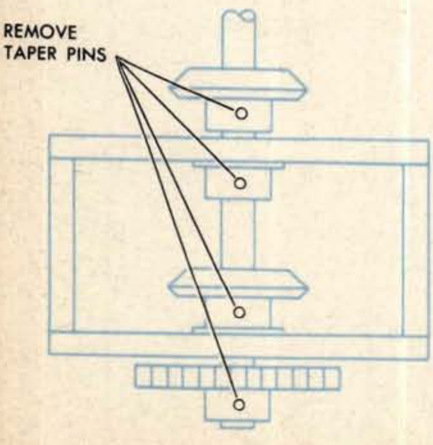


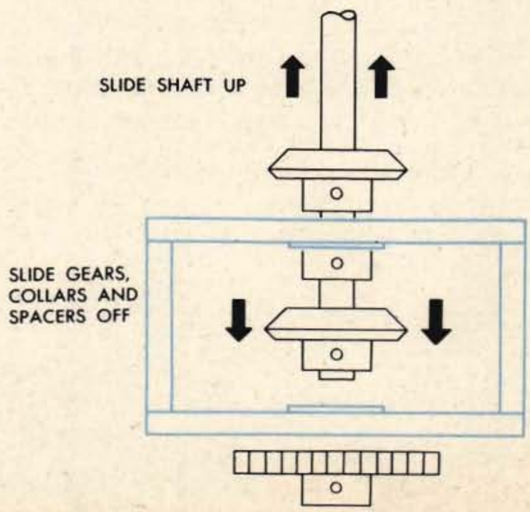
To remove a shaft assembly mounted between plates, it is often possible to remove the upper plate by unscrewing all the screws and lifting the plate straight up to clear the shafts.

If neither plate can be removed conveniently, it may be necessary to remove one or more taper pins in order to remove an assembly.



The screws and any accompanying small parts are removed in the same way as from hanger-mounted assemblies. In raising an upper plate, be careful to keep it parallel to the lower plate until the shafts are cleared. Be very careful not to lose any spacers that may adhere to the under side of the plate.

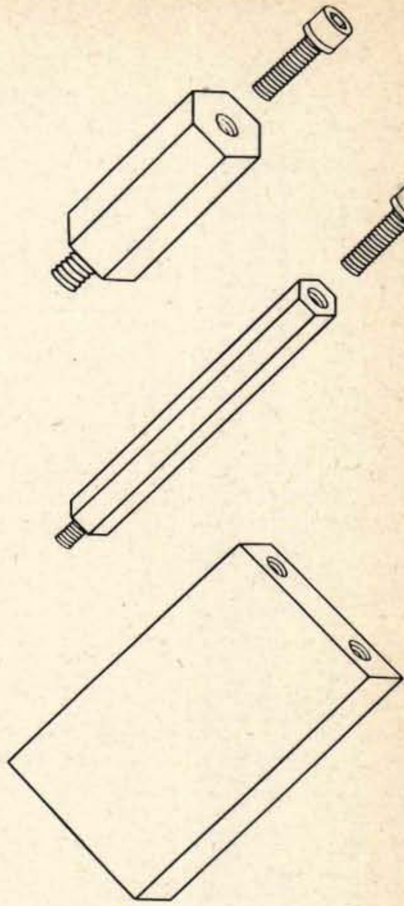




Some plates are supported by posts, or by both posts and plates.

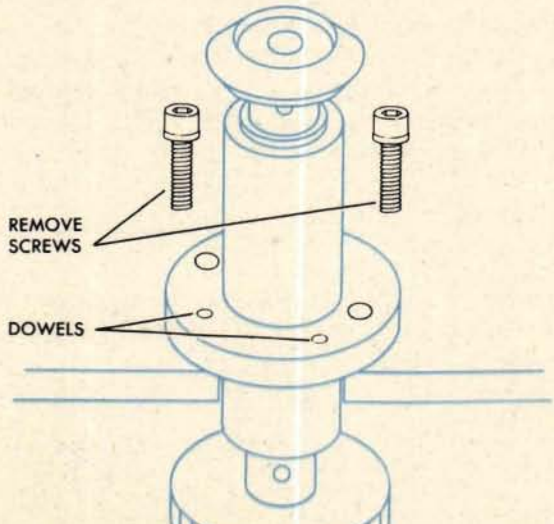
The most common type of post is a hexagonal bar with one end machined down and threaded to form a screw and the other end drilled and threaded to receive a screw.

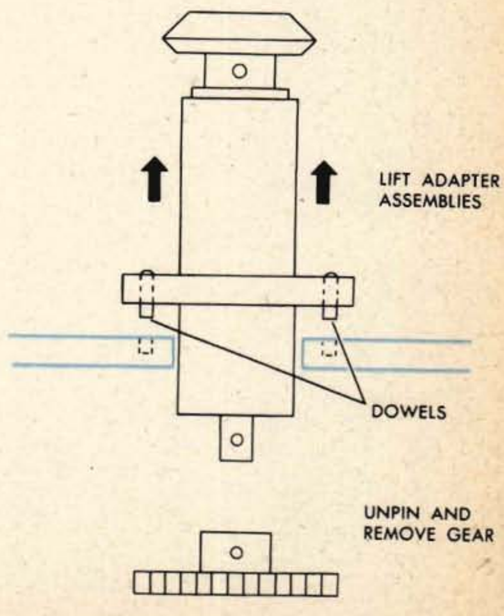
Another type is an oblong bar drilled and threaded at both ends to receive screws.

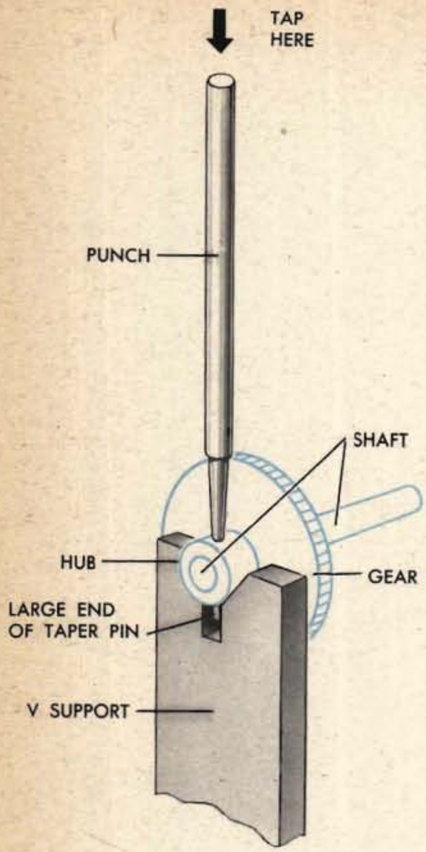


Plates may be removed from posts or posts from plates after the screws have been loosened and taken out. Most hexagonal posts can be unscrewed by hand, but sometimes a hole is provided to receive a round shaft which serves as a lever.

An adapter assembly is removed by taking out the screws and lifting the assembly straight up until the dowels clear the plate. Be careful not to cock the assembly during removal, because cocking it may bend or distort some part of the assembly.





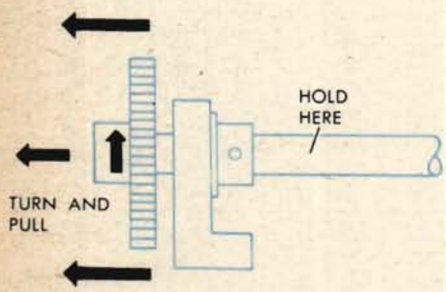


Unpinning and removing gears and collars

Always remember that most of the pins used to hold parts on shafts are tapered, and that a small amount of metal is staked over the large ends to hold the pins in place. It is therefore very important to start the pin out by tapping it sharply *from the small end.*

To avoid bending the shaft, place a V block or pinning support directly under the large end of the pin and keep the pin vertical. Use a light hammer and a pin punch held in a vertical position on the small end of the pin to drive it out. It is better to start the pin with a few light, sharp blows than with a heavy one which may bend or distort the parts. Once the pin is started, it should tap out easily.

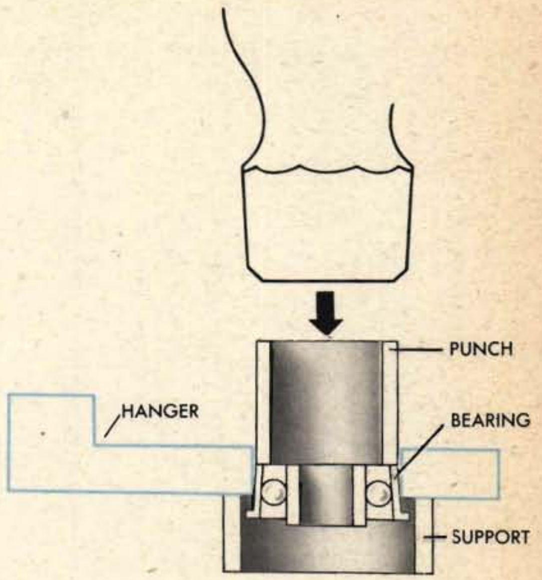
To remove a gear or collar after unpinning it, grasp the shaft in one hand and pull off the part with a slow, turning motion. If it cannot be removed this way, apply a drop of oil and tap the end of the shaft with a light hammer until it comes free.



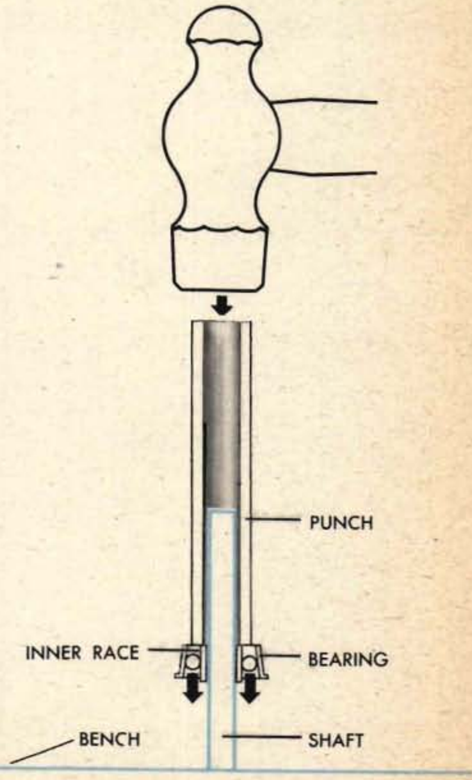
Filing off the burr formed on the shaft by the set screw will simplify removal of the other parts.

Removing bearings

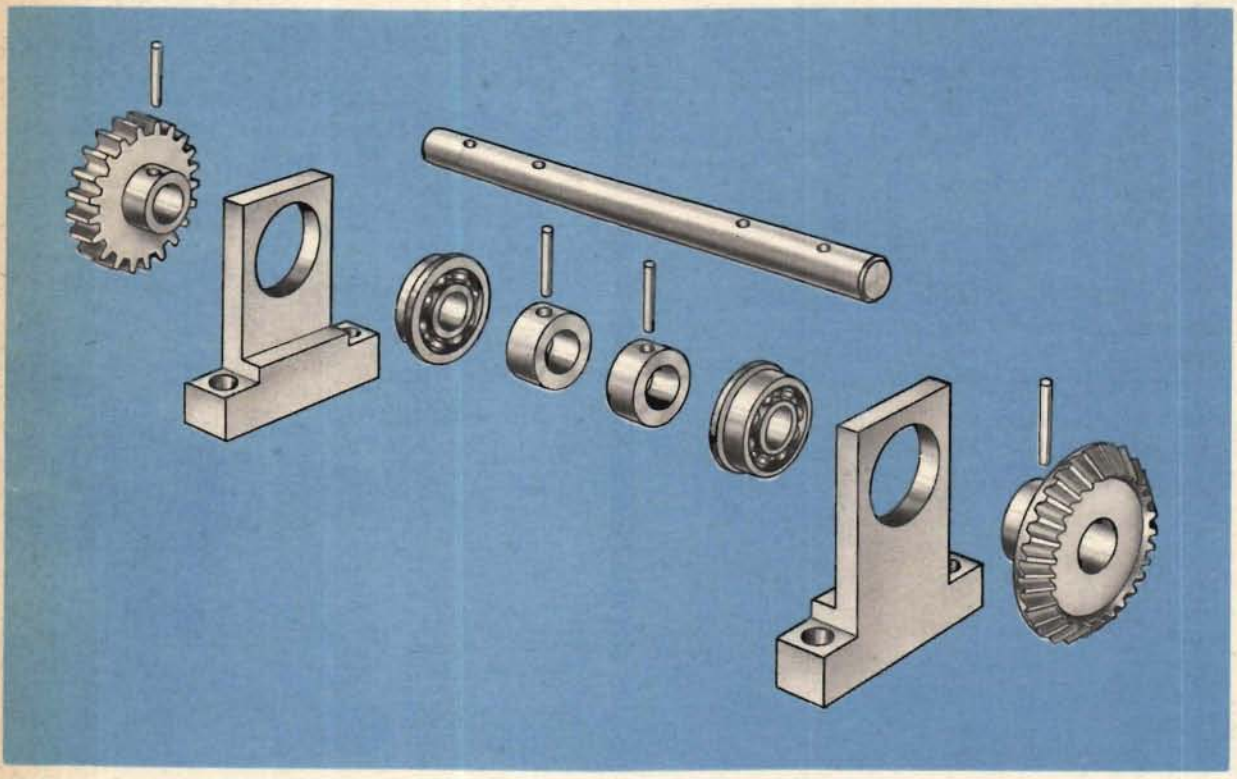
To remove a bearing from a hanger, use the bearing punch and the support described on page 30. The support is a piece of tubing of the proper diameter to fit around the bearing and up against the hanger. The punch is a piece of tubing which fits on the outer race of the bearing. Place the hanger on the support and the punch on the bearing. Using a light hammer, tap the bearing punch until the bearing drops out of the hanger hole.

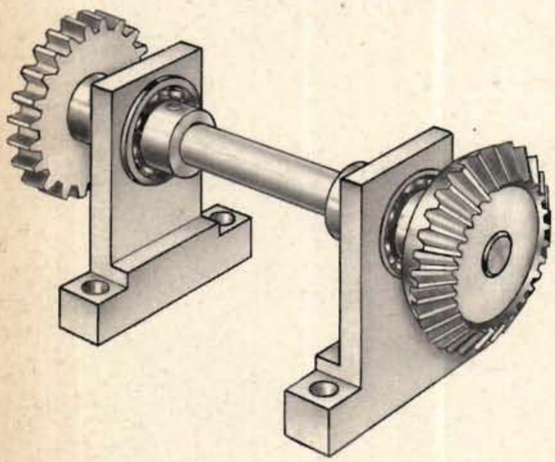


If a bearing freezes to a shaft, stand the shaft upright on the bench and slip a tubular bearing punch over the shaft. The punch must fit directly on the inner bearing race. Place a drop or two of oil on the shaft and tap the punch with a light hammer until the bearing comes loose.



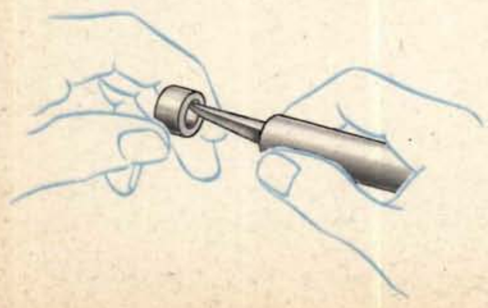
Preparing new parts





Here are new parts of a typical shaft assembly: one shaft, two hangers, two bearings, two collars, two gears, and four taper pins. The basic operations of preparing these parts for assembly may be applied to any shaft assembly repair job, in whole or in part, as required.

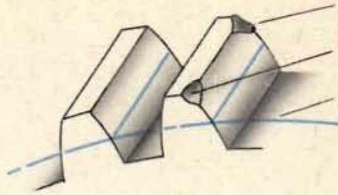
Whenever a new part is used, remove the rust-preventive coating.



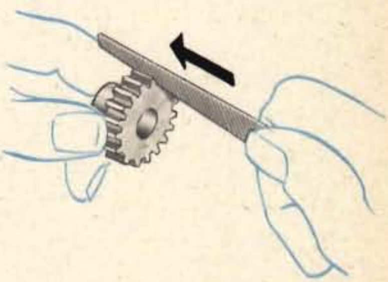
Scraping and filing the parts

Use a handscraper to break the sharp edges of the holes in the parts.

Inspect the gear teeth for nicks and burrs. Small nicks will not cause faulty operation of a gear, but a raised burr may cause meshing gears to bind.



Use a needle file to remove burrs. When filing a burr, be careful not to change the shape of the tooth.



Checking bearing smoothness

Check each bearing for smoothness. Hold it by the outer race in one hand, and turn the inner race with a finger of the other hand. Any roughness or stickiness indicates foreign matter in the bearing or some mechanical imperfection.

If the bearing does not operate smoothly, wash it in solvent, dry it, and check it again. Wash it several times, if necessary. If it is still rough or sticky, use a different bearing.

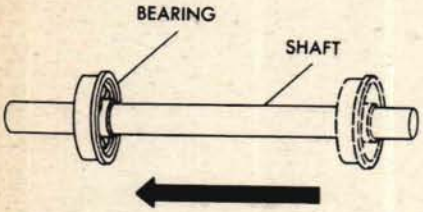
A bearing cannot be altered to fit a shaft or a hanger. If a bearing does not fit properly, the shaft must be reduced, or the hole enlarged in the hanger.

Washing the parts

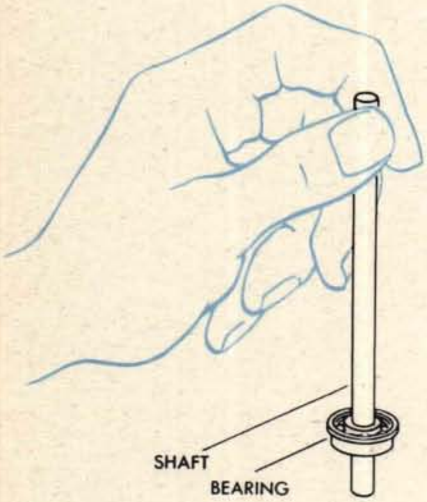
After the part has been prepared for installation, wash it thoroughly in solvent to remove dirt, grit, or chips. Dry and lubricate it before fitting.

Fitting the parts

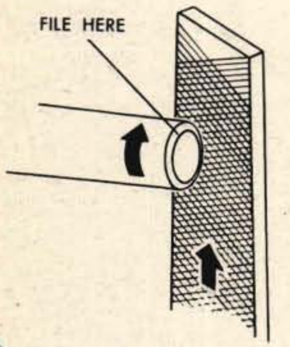
Fitting a shaft to a bearing



Before trying a bearing on a shaft, wipe the shaft with an oiled rag to prevent sticking. During all shaft-fitting operations, try the bearing frequently, wiping the hands and the shaft clean each time the bearing is handled.



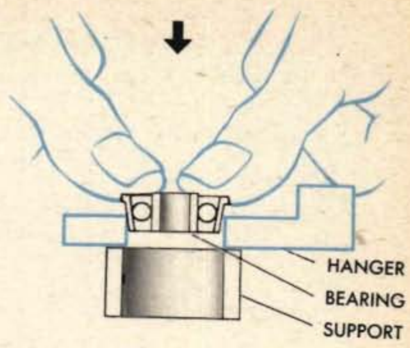
A properly fitted shaft will allow the bearings to be pushed over its entire length by hand, but will not let them slip off if it is held in a vertical position.



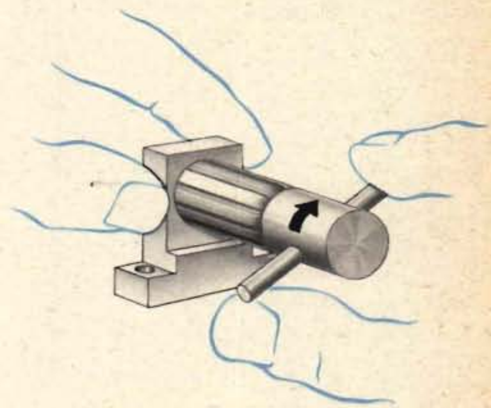
If a bearing does not go on a shaft properly, do not attempt to force it on. Forcing a bearing may damage the balls or raceways, or spring the retainer. Run a file lightly around the chamfered ends of a shaft to remove the burrs, and try the bearing again.

If a bearing will not pass over the entire length of the shaft without sticking, polish the shaft evenly, until the proper fit is obtained. This may be done by hand, but a smoother and more even job can be done if the shaft is rotated in a chuck mounted on a lathe, motor, or drill press. Try the bearing on the shaft frequently to avoid reducing the shaft too much.

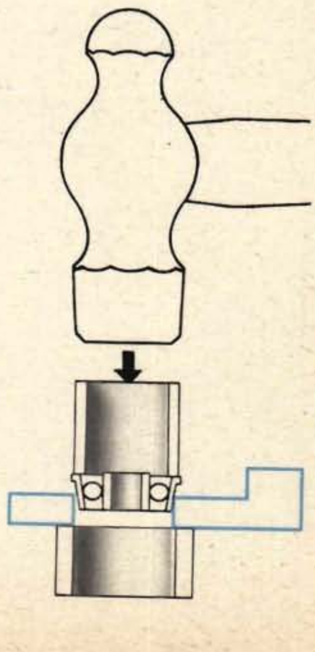
Fitting and seating a bearing in a hanger



Start the bearing into the hanger hole from the side indicated on the assembly drawing. If the fit is correct, the slightly tapered bearing will press against the sides of the hole when the bearing is about 1/32 inch from the seat.



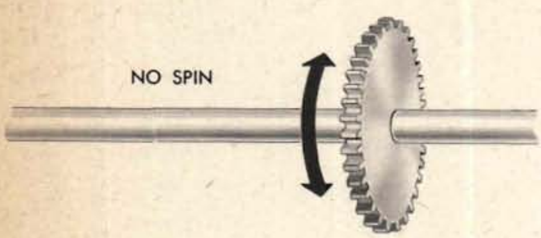
If the bearing cannot be pressed into the hole the proper distance by hand, the hole must be enlarged a little with a special bearing reamer. It is important to insert the reamer from the same side as the bearing, because this reamer has a slight taper. Float the hanger by allowing it to take its own position on the reamer without any hand pressure. Enlarge the hole slightly by slowly turning the reamer. Remove only a small amount of metal before trying the bearing in the hole.



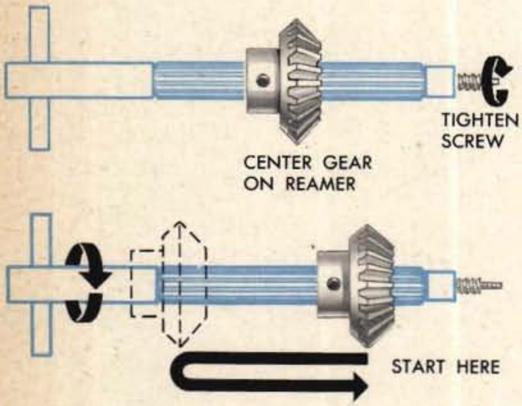
When the proper fit is obtained, seat the bearing. Use a light hammer and the punch and support described on page 30. The support fits around the bearing hole and against the hanger. The punch must fit over *the outer race* of the bearing.

Finally, check the bearing for smoothness and wash the assembly.

Fitting gears and collars to a shaft



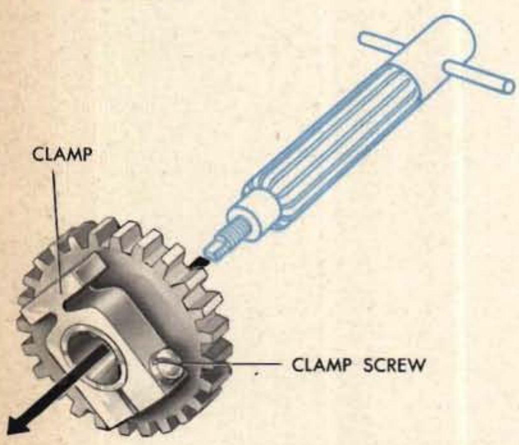
Collars and gears should fit on the shaft with a sliding push-fit. If they can be made to spin on the shaft, they are too loose and should not be used.



If a collar or gear is too tight, enlarge the hole with an expansion reamer the same size as the shaft. Before reaming, back out the set screw to avoid damaging the reamer. Position the gear or collar over the center or largest part of the reamer. Tighten the reamer screw until a slight drag is felt when the reamer is moved. Now turn the full length of the reamer through the hole and then draw the reamer back out. Try the collar or gear on the shaft. Repeat the reaming operation if necessary until the hole is the proper size for a sliding push-fit.

After the collar or gear is properly fitted, insert the set screw and mount the part in its approximate position on the shaft.

REAMING A CLAMP



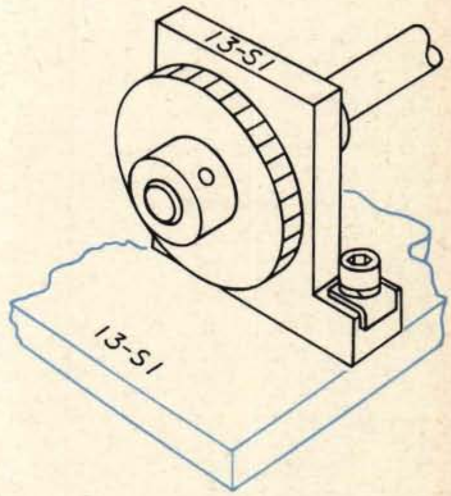
Fitting a clamp gear to a shaft

If a clamp gear is too tight, slip the clamp over the adjustable split gear hub before reaming the hole. Do not tighten the clamp screw, but turn it until it just takes hold. Start the reamer into the hole from the solid end of the hub. Ream the hole according to the directions given above for collars and gears.

Mounting an assembly on a plate

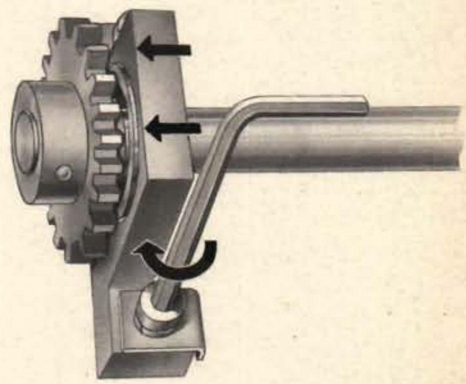
Positioning hangers

Hangers are usually positioned and held in place on a plate by means of screws, lock washers, and lug plates. The holes in the plate are accurately located to make it possible to position each hanger within close limits.



The shaft assembly number indicated on the drawing should be stamped or etched on a new hanger before it is installed. In mounting a new hanger, remember that lock washers will damage any material softer than steel. Always use lug plates, lug washers, or straddle plates between lock washers and any softer material.

Always remember to lubricate the screws before inserting them.

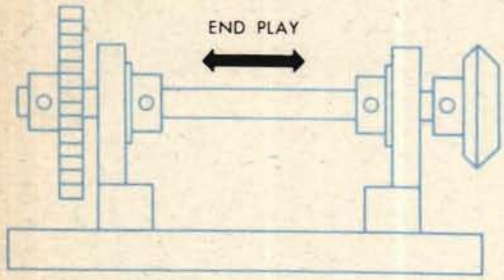


SQUARING A HANGER

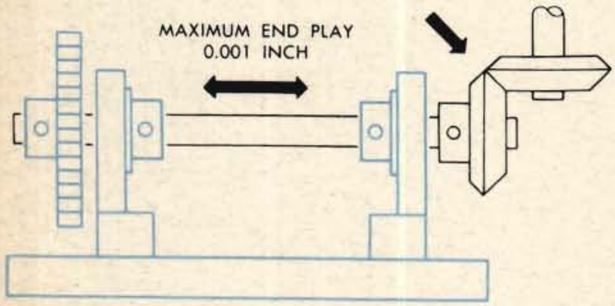
To square a hanger, move it toward its end of the assembly and against the screws before tightening the screws.

Often a mounted hanger can be repositioned by loosening the screws and shifting the hanger slightly in the required direction. If screws are loose or missing, a hanger can be repositioned and held by tightening or replacing the screws.

Reducing end play

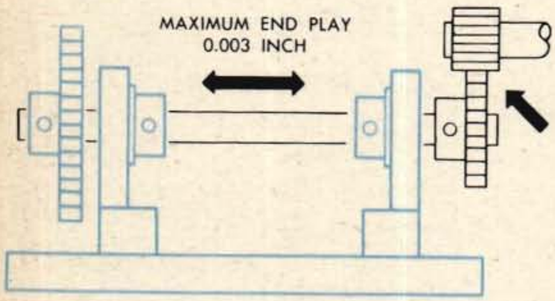


End play is the lengthwise, or back-and-forth, movement of a shaft within its assembly. Gears and collars press against the bearings and thus control end play in a shaft assembly.

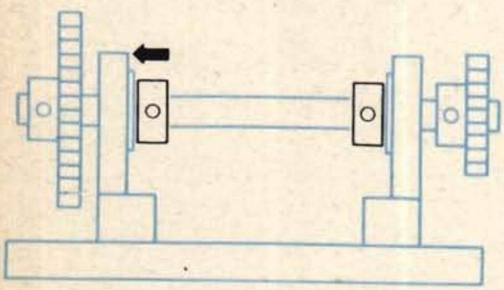


Beyond very small limits, end play is undesirable because it affects the gear meshes.

A shaft with one or more bevel gears should have no more than 0.001-inch end play.

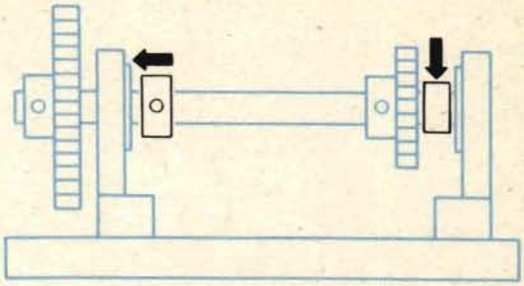


A shaft with spur gears only may have up to 0.003-inch end play.

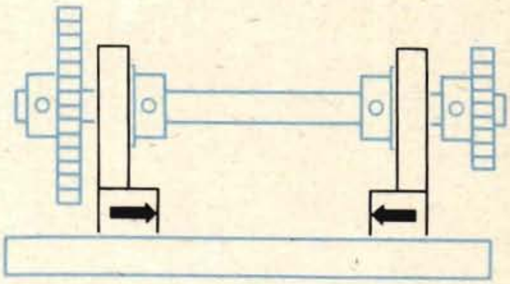


Move the collar or gear against the bearings until end play cannot be felt, yet the shaft turns freely. Then tighten the set screw to hold the collar or gear in position until it is pinned.

Excessive end play can often be remedied by repositioning a collar at one end of an assembly, or by installing a longer spacer at the other.

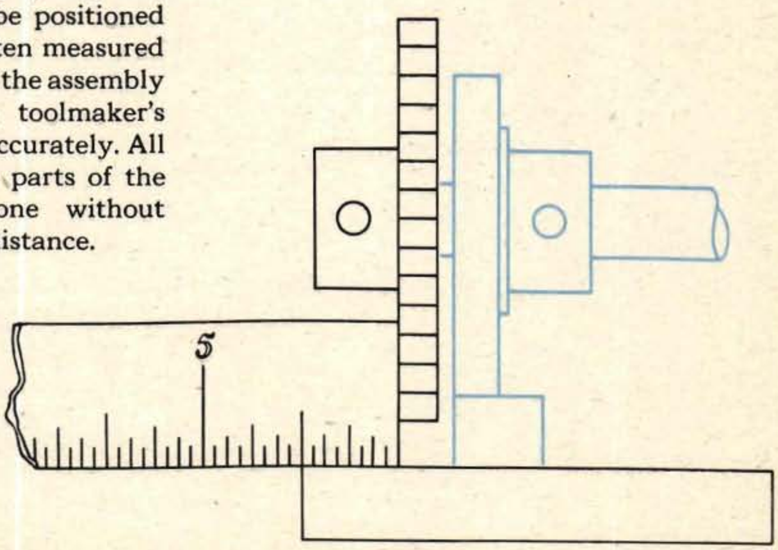


Sometimes end play can be reduced sufficiently by loosening the hangers and moving them in the proper direction.

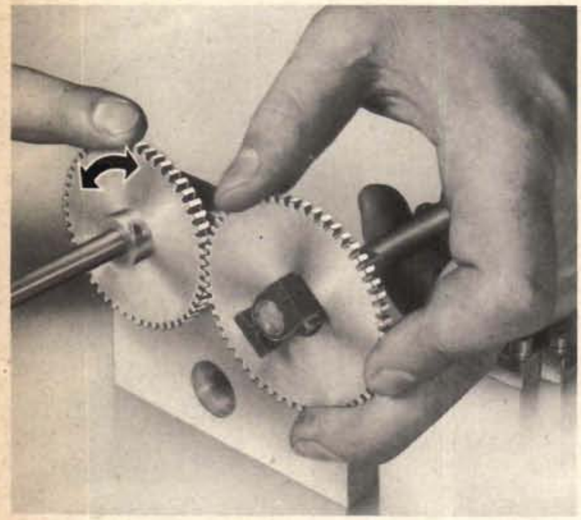


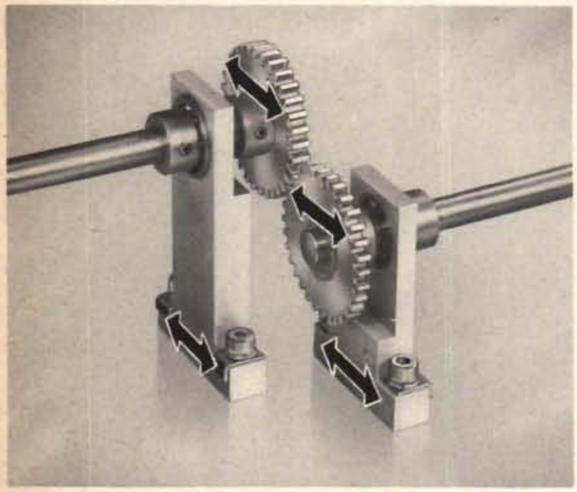
Positioning a gear to a given dimension

An assembly drawing may specify that a particular gear must be positioned to a given dimension, often measured from the side of the plate the assembly is mounted on. Use a toolmaker's scale to position a gear accurately. All positioning of the other parts of the assembly must be done without changing this specified distance.



Positioning gears for proper mesh





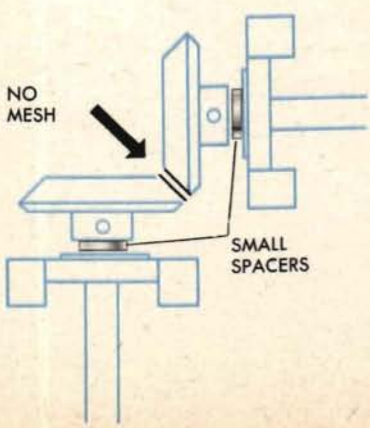
Properly meshed gears make contact evenly all along the surfaces of the teeth, with only a very small amount of lost motion between the teeth of one meshing gear and those of the other.

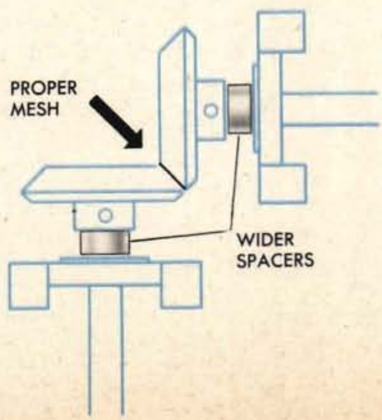
Lost motion is the distance the driver gear turns before the driven gear begins to turn.

It may be measured with a dial indicator, or estimated by holding one gear stationary and gently rocking the other.

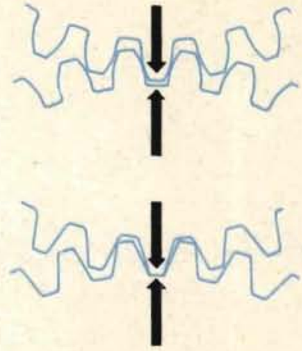
If there is no lost motion at all, the gears are too tight. If there is over 0.002 inch, they are too loose. Either tight or loose gears must be repositioned.

Gears can be positioned for correct lost motion by moving them together or apart by various mechanical means, according to the particular assemblies. Hangers may be shifted slightly, spacers and collars may be filed or longer spacers installed, or a gear may be moved into a new position on its shaft.

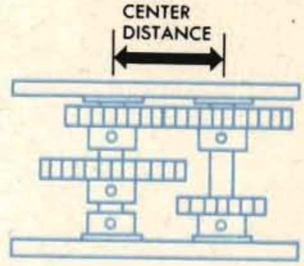




If the teeth are worn too much, new gears should be installed. New gears are cut so that there is a clearance between the tops of the teeth on one gear and the bottom of the spaces between the teeth on the other. If the teeth are worn so that this clearance is lost when gears are moved together, they are said to bottom. Never attempt to reduce lost motion in gears which bottom, because they cannot be made to run smoothly. They must be replaced.



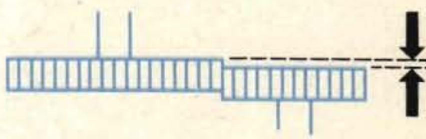
Gears on a fixed center distance cannot be moved to reduce excessive lost motion and therefore must be replaced.



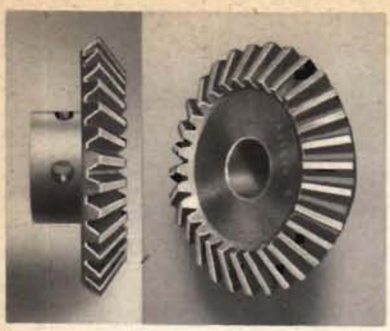
Positioning spur gears

Spur gears should be positioned for correct lost motion and proper alignment of the gear faces. There should be some lost motion, but not over 0.002 inch.

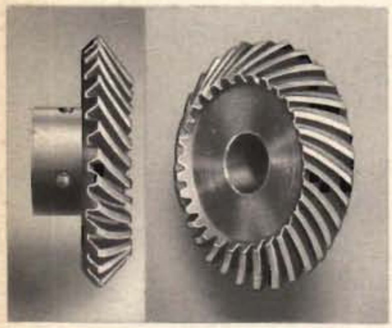
If the gears are of the same thickness, their faces should be flush within 0.010 inch after they have been adjusted for correct end play.



If they are not of the same thickness, the thinner one should be centered on the other.



STRAIGHT-TOOTH BEVEL GEARS

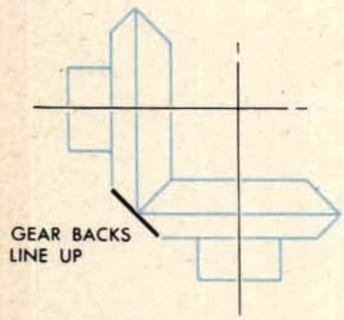


SPIRAL-TOOTH BEVEL GEARS

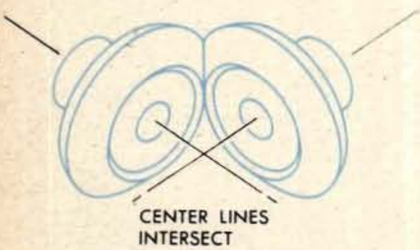
Positioning bevel gears

Because bevel gears are always mounted at an angle to each other, positioning them involves special problems. The spiral-tooth and the straight-tooth bevel gears are the two types in common use. The procedure for positioning them is the same for both, except that the curved teeth of the spiral bevel gear make each movement more critical. Care must be exercised in positioning either type, but very particular care must be taken to obtain a correct spiral bevel gear mesh.

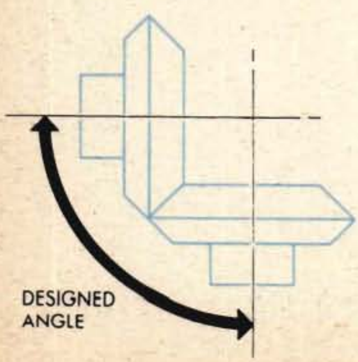
Essentials of a good bevel gear mesh



The backs of the gears must line up.



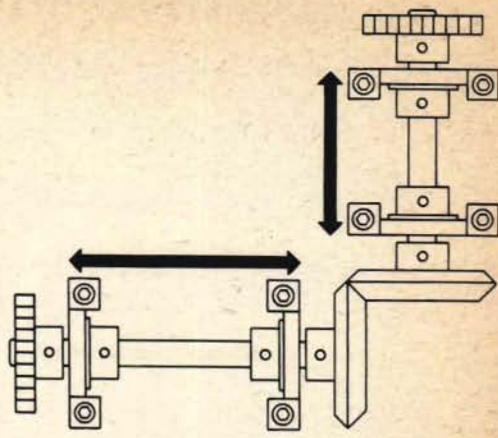
The centerlines must intersect. If the bearing holes in the hangers are the same height from the plate, this condition is established.



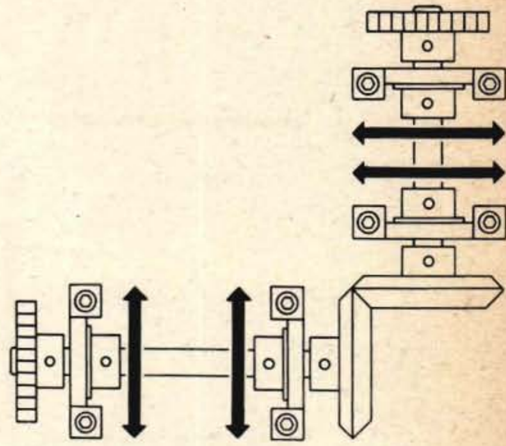
The gears must mesh at the angle for which they were cut.

If these three essentials of a good bevel gear mesh have been satisfied, the gears will run quietly and smoothly. Proper lubrication will prevent undue wear. The wearing action of normal operation should make the tooth faces appear uniformly smooth.

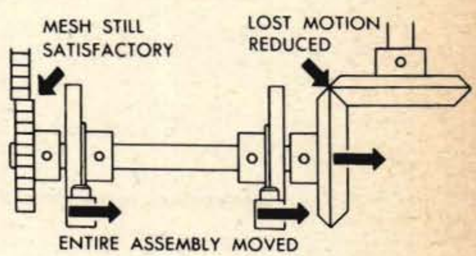
As a general rule, it is best to obtain a proper bevel gear mesh by moving both shaft assemblies equal distances *in the direction of their shafts* rather than sidewise.



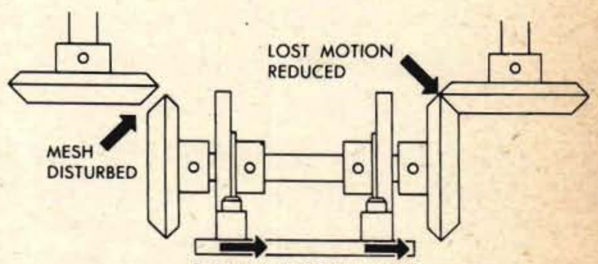
But there are exceptions. Sometimes both *entire* shaft assemblies can be moved together or apart by shifting all four hangers a little to one side or the other. If a shaft is very long, a slight sidewise shift at one end may not seriously affect the mesh at the other. To determine the best way to position a bevel gear mesh, closely examine all the affected gears and the related shafting and gearing.



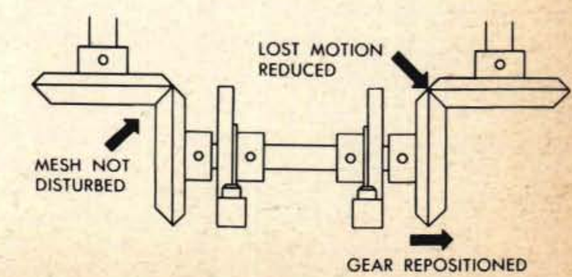
Moving bevel gears in the direction of the shaft



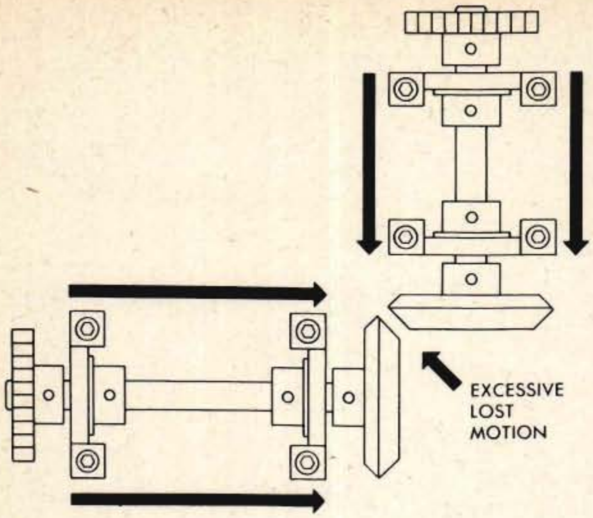
A shaft assembly having only one bevel gear can be positioned to reduce lost motion or to free a tight mesh more easily than an assembly having two or more bevel gears.



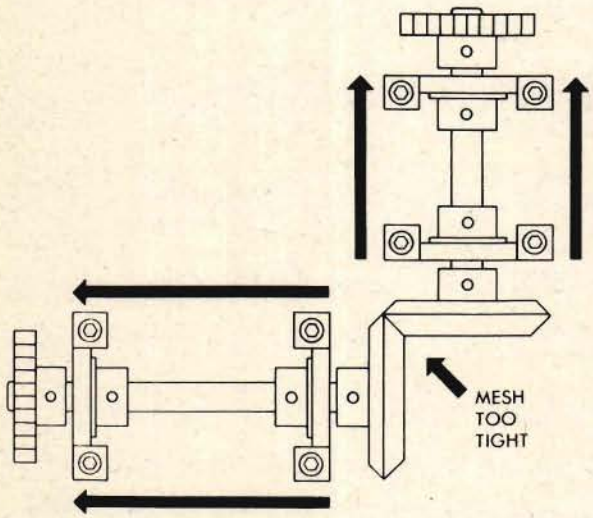
If an assembly with two or more bevel gears is moved to improve one bevel gear mesh, the other meshes may be disturbed.



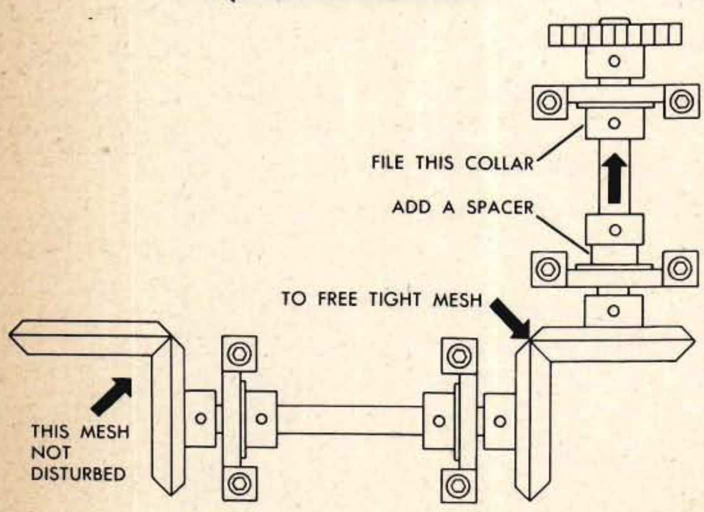
To avoid this, it is often necessary to unpin and move the particular gear which must be repositioned. For an explanation of the method of moving a gear, see pages 66-67.



TO REDUCE LOST MOTION in a bevel gear mesh where each assembly has only one bevel gear, move both assemblies in the direction of the shaft *toward* the meshing gears. Shaft assemblies mounted on hangers may be moved by loosening the screws and shifting the hangers. The hanger holes may be enlarged slightly, if necessary.

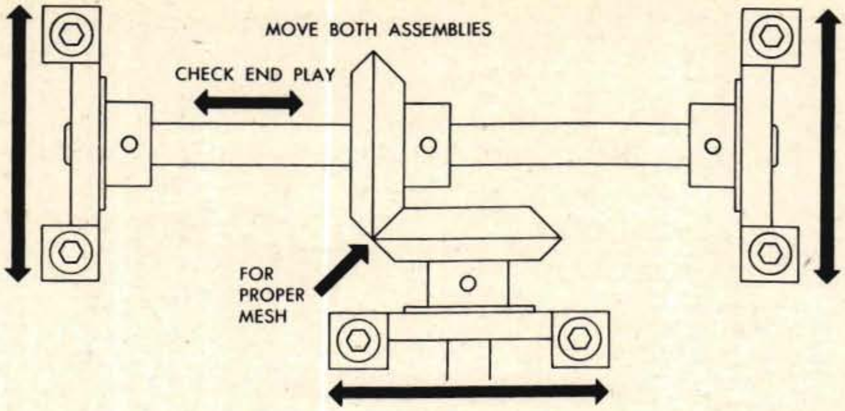


TO FREE A TIGHT BEVEL GEAR MESH, move both shaft assemblies in the direction of the shaft *away from* the meshing gears. Check the assemblies for correct end play.



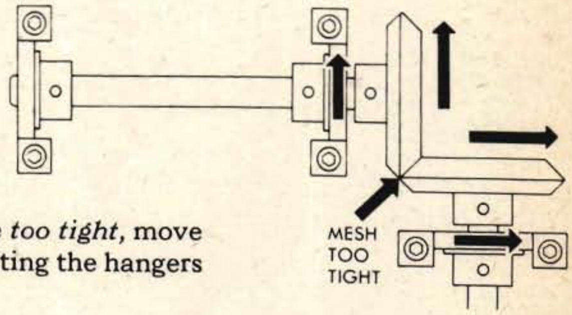
Sometimes it is necessary to install thicker spacers, or to file collars or spacers in order to obtain a good bevel gear mesh. To reduce the thickness of spacers and collars most accurately, use the spacer-filing fixture described on page 31.

Moving bevel gear assemblies sidewise

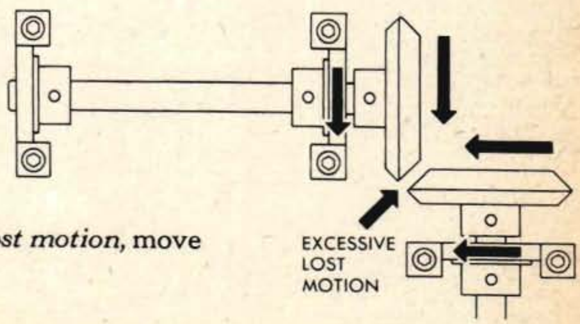


Often bevel gears can be repositioned most easily by shifting hangers slightly to one side or the other. It is important to move each assembly the same distance as the other, and at the proper angle. Whenever a hanger is moved, the whole assembly should be checked for correct end play. It may be necessary to install a thicker spacer, or to file a collar or spacer.

To obtain a good bevel gear mesh where the assemblies have been in use, first inspect the gear teeth for wear.

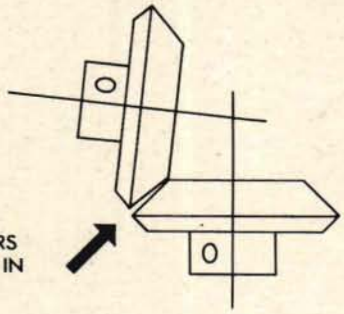


If they are worn evenly and the mesh is a *little too tight,* move the assemblies apart at the affected ends by shifting the hangers slightly sidewise.

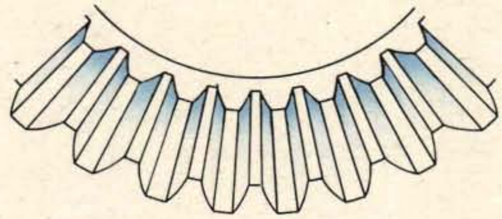


If they are worn evenly and there is *excessive lost motion,* move the assemblies together in the same way.

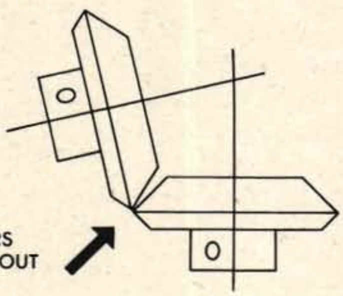
If bevel gears toe in—that is, they mesh at an angle greater than the angle for which they were designed—signs of wear appear on those areas of the tooth faces nearest to the center of the gear.



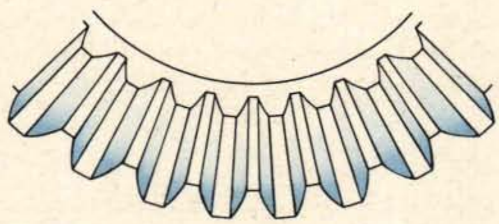
GEARS TOE IN



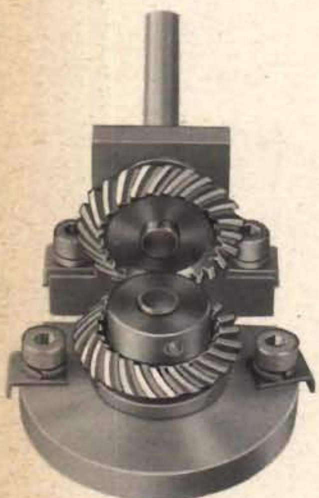
If they toe out, signs of wear appear on the areas of the tooth faces farthest from the center of the gear.



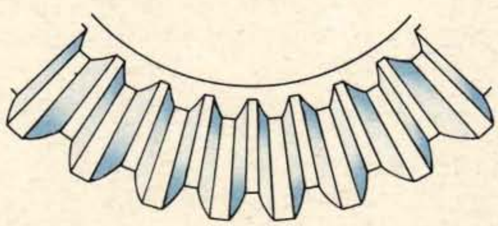
GEARS TOE OUT



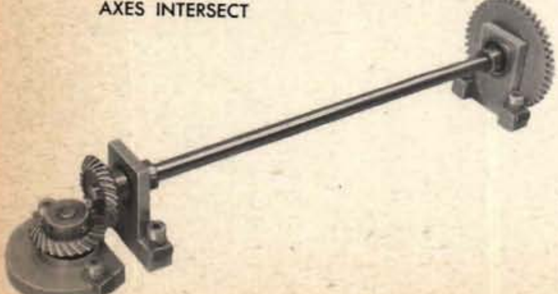
The shaft axes of meshing bevel gears must intersect. If they do not, the mesh will feel rough and sound noisy even though the end play and lost motion seem to be correct. Signs of wear will appear on the opposite ends of alternate tooth faces, as shown.



AXES INTERSECT

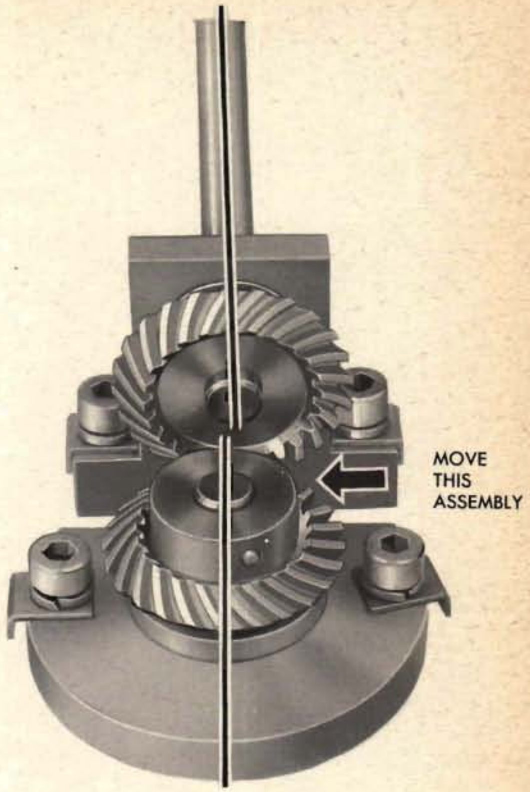


Bevel gear meshes most susceptible to this type of misalignment are those where one shaft is parallel to the mounting plate and the other is perpendicular to it.



A very slight movement of a hanger within the limits of the clearance holes will cause a marked difference in a bevel gear mesh. If the shaft axes do not intersect, loosen one of the hangers and move the shaft assembly sidewise until the shaft axes appear to be correctly aligned. Then check the mesh for freedom of movement.

When the shafts are properly aligned and the gears turn freely, check the assembly for end play and lost motion. Secure the assembly in place. Recheck the gear mesh for freedom of movement and lost motion, and the shaft for end play.

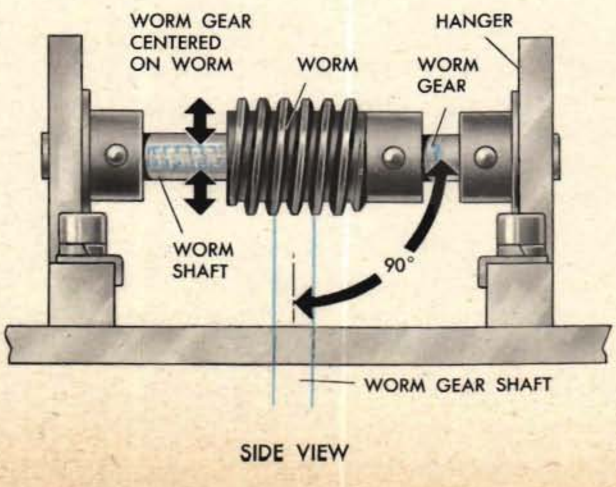


AXES NOT INTERSECTING

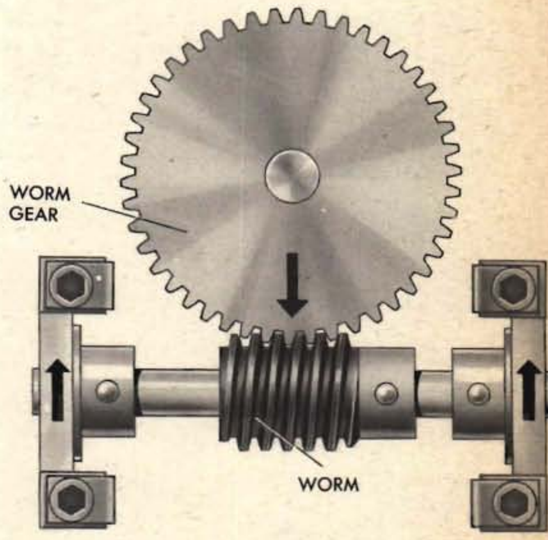
Positioning worm gears

A good worm gear mesh is obtained by moving whichever gear can be moved most easily toward the other. The worm gear must be centered on the worm and the two shafts positioned at right angles to each other.

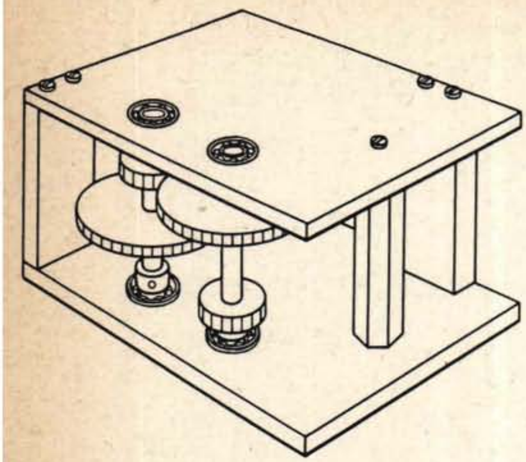
For efficient transmission of values, lost motion between the worm and the wheel must be kept at a minimum. End play in the worm shaft must also be kept at a minimum because it has the same effect on the mesh as lost motion between the gears.



SIDE VIEW



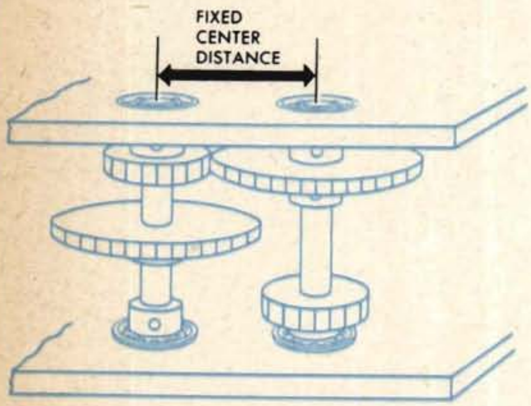
TOP VIEW



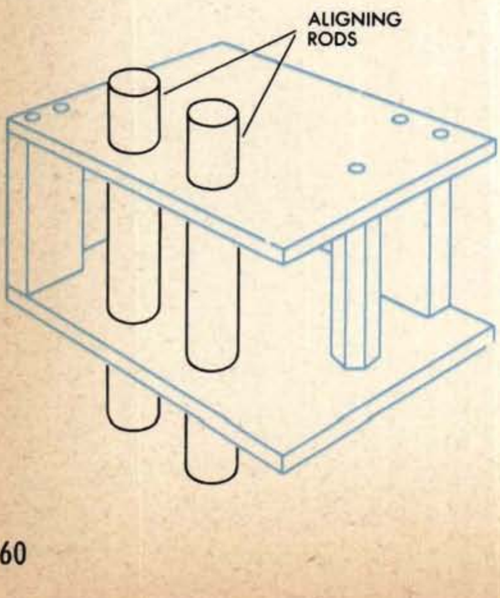
Positioning gears in a box assembly

In a box type of assembly, gears cannot be easily repositioned because the shafts are mounted in bearings fitted in fixed plates instead of movable hangers.

End play may be reduced by installing longer spacers, or increased by filing collars or spacers.



Lost motion at the gear meshes is not so easily controlled, however. Because of the fixed positions of the shafts in the bearing holes in the plates, each pair of meshing gears is positioned at a fixed center distance. When the construction of the parts establishes a fixed center distance, lost motion due to worn gear teeth can be reduced only by installing and fitting new gears.

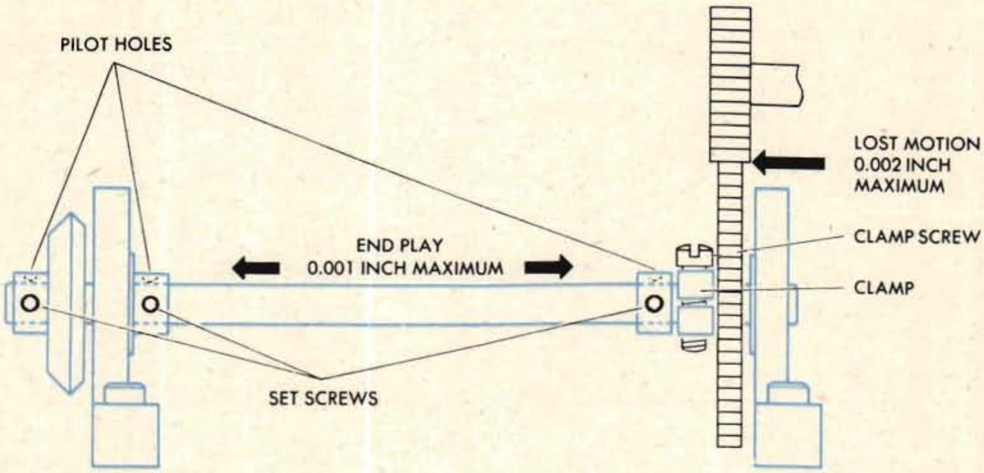


For proper operation, the plates must be parallel with each other, and the bearing holes must be perfectly aligned. The alignment may be checked by pushing close-fitting rods through the holes. Lubricate the rods before making this test.

Pinning the parts

After the parts of a shaft assembly have been correctly positioned in the instrument and the set screws have been tightened, the entire assembly must be removed for pinning. A complete pinning operation includes drilling the holes, seating the pins, and staking the pins. Each of these steps must be done very carefully.

Essentials of a correctly positioned assembly



Before removing an assembly from an instrument for pinning, check to be sure that the following five conditions have been established:

All pilot holes in hubs and collars should be in a straight line, so that when the holes are drilled through the shaft, their centers will lie in approximately the same plane.

All set screws are in place and tight.

Clamp gears hold tight to the shaft when the clamp screws are tightened. The clamp must hold the hub on the shaft without a complete closing of the clamp slot.

Shafts with straight-tooth spur gears turn freely, with 0.0005 to 0.003 inch end play. Shafts with one or more bevel gears, worms, or helical gears, turn freely with not more than 0.001 inch end play.

Lost motion between gear teeth does not exceed 0.002 inch. This applies to spur, helical, bevel, and worm gears.

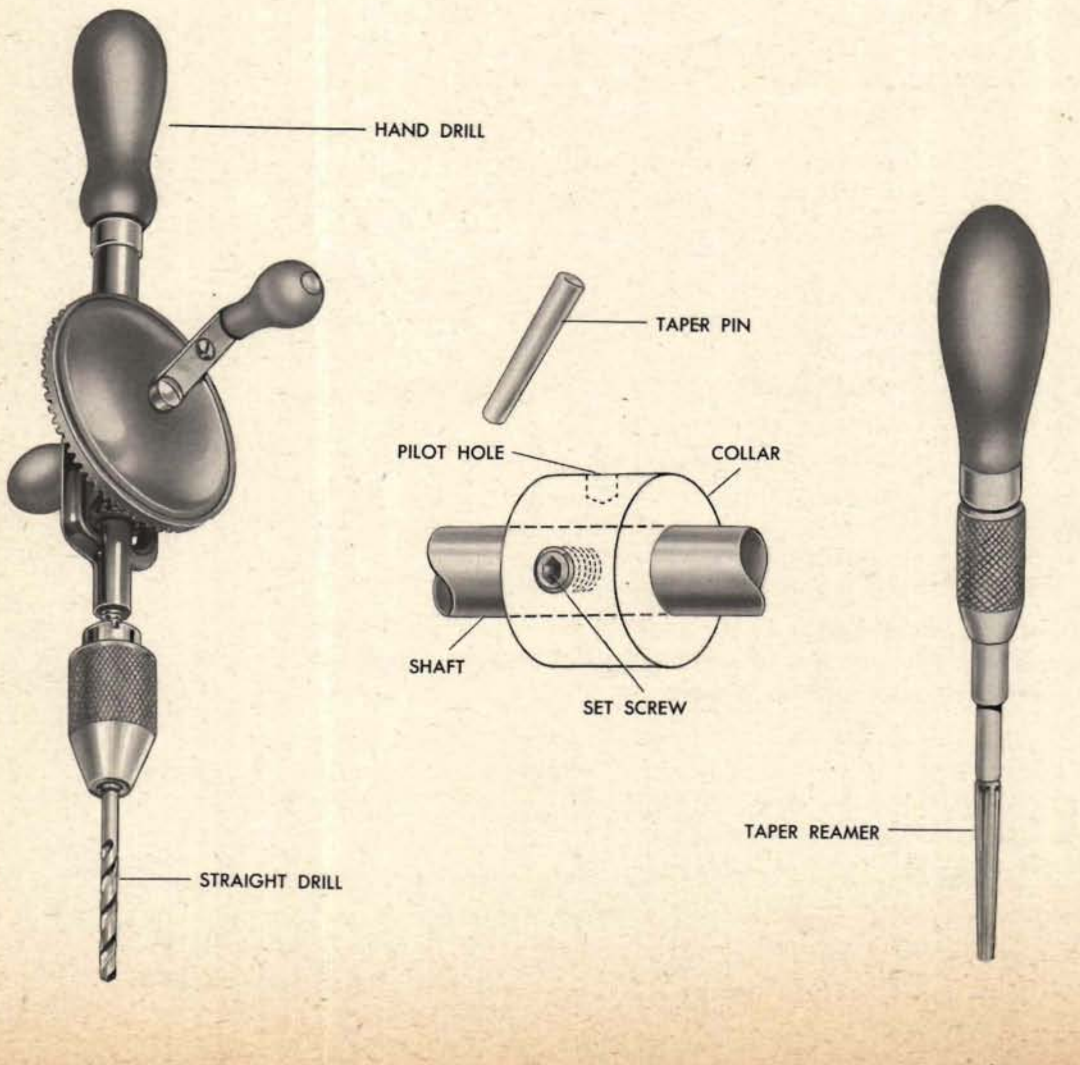
In removing a shaft assembly from the instrument for pinning, *be very careful not to disturb the set screws or nick the gears.*

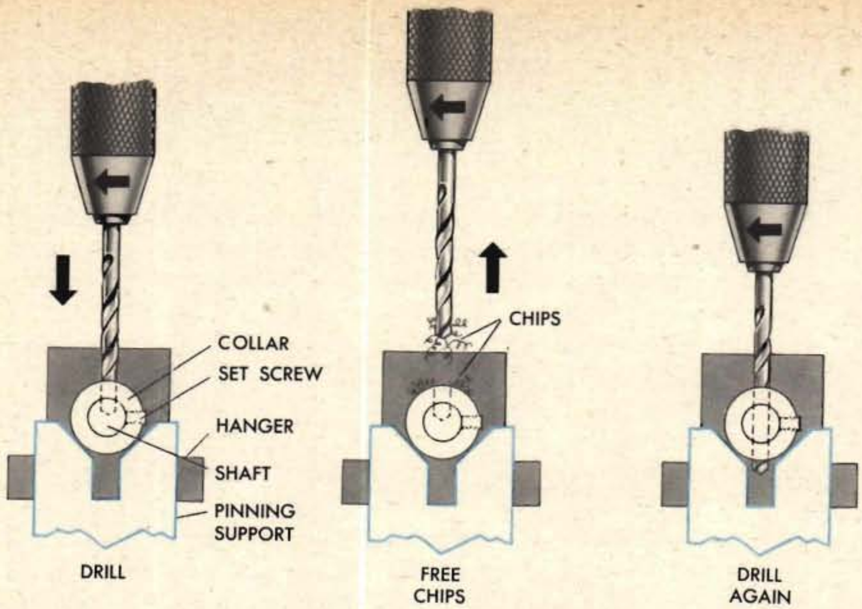
Drilling a shaft

There are two entirely different methods of drilling a shaft when a new gear or collar is used: a factory method for large-scale production, and a trouble-shooter's method for single repair jobs on the bench. Whichever method is used, the collar or hub is provided with a pilot hole spotted about halfway through one side to guide the drill.

The factory method involves using a taper drill in a drill press equipped with an automatic stop.

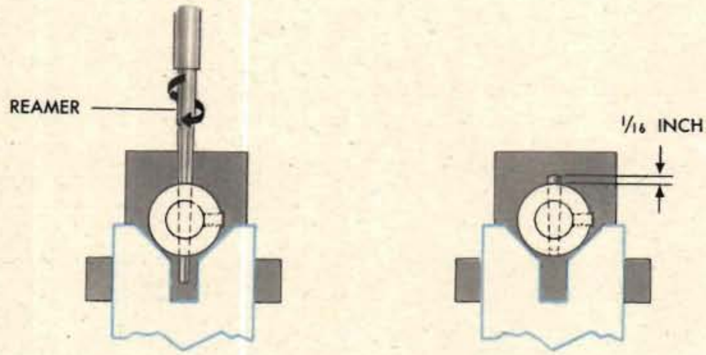
The trouble-shooter's method requires a standard straight drill, slightly smaller than the small end of the pin, and a taper reamer the same size as the pin. The taper pin must be selected according to the size of the shaft and the collar or hub to be pinned to it.



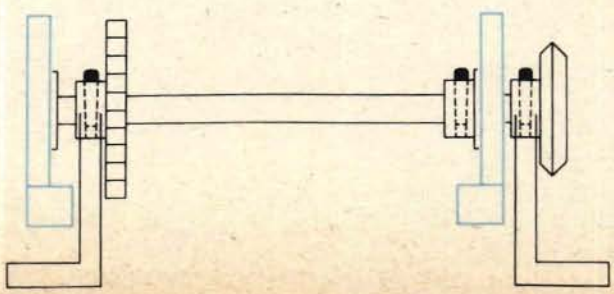


To avoid bending a shaft during drilling, it is important to place a pinning support directly under the collar or hub. The drill should be held perpendicular to the shaft axis. Lubricate the drill before using it, feed it slowly, and remove it from the hole often to free the metal chips. When the drill breaks through the opposite side of the collar or hub, remove it and clean out the hole.

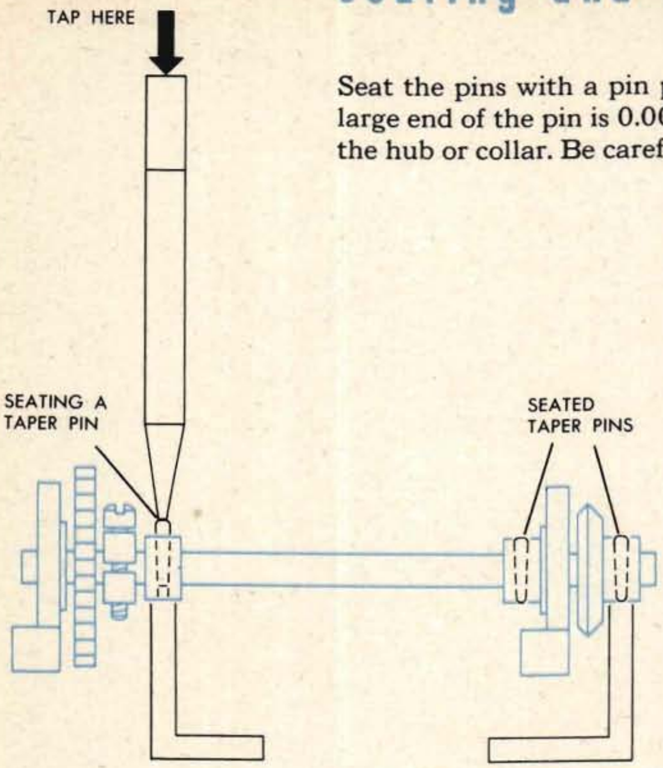
Lubricate the hand taper reamer and ream the hole until the pin enters to within 1/16 inch of its final position.



Drill and ream all the holes the assembly requires before seating the pins. After each hole has been drilled and reamed, insert the taper pin and leave it in place.

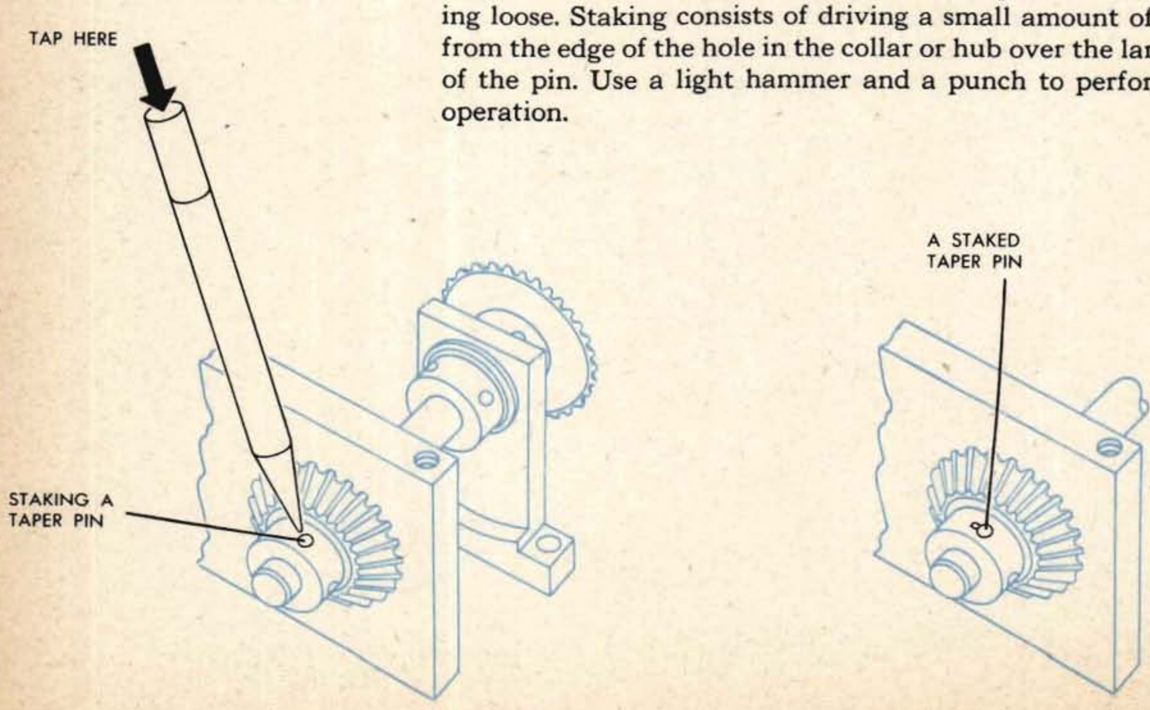


Seating and staking taper pins



Seat the pins with a pin punch and light hammer so that the large end of the pin is 0.005 to 0.010 inch below the surface of the hub or collar. Be careful not to bend the shaft.

The pins should be staked in position to keep them from working loose. Staking consists of driving a small amount of metal from the edge of the hole in the collar or hub over the large end of the pin. Use a light hammer and a punch to perform this operation.



Marking a gear position for pinning

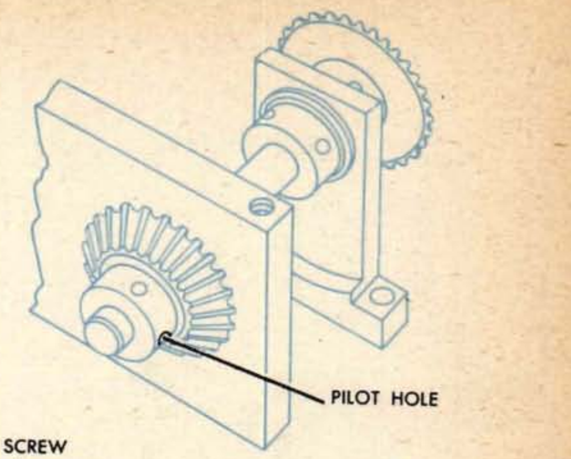
Sometimes a shaft is mounted through a plate with a gear on one side of the plate and the rest of the assembly on the other.

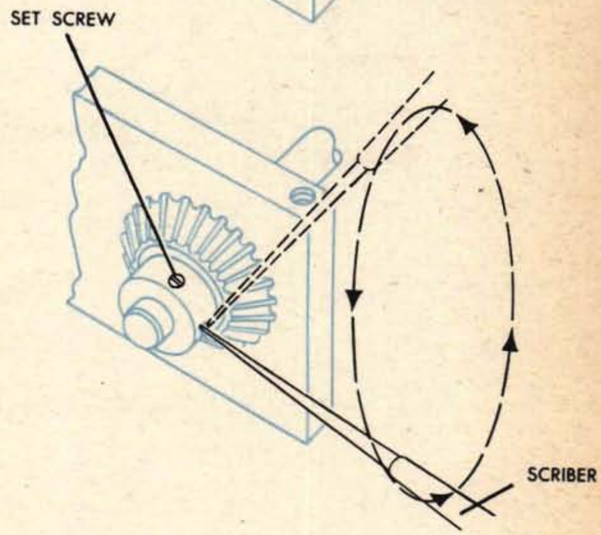
Before a new gear is mounted outside the plate for positioning, the pilot hole must be drilled through to the shaft hole so that the correct gear position can be marked on the shaft for drilling.

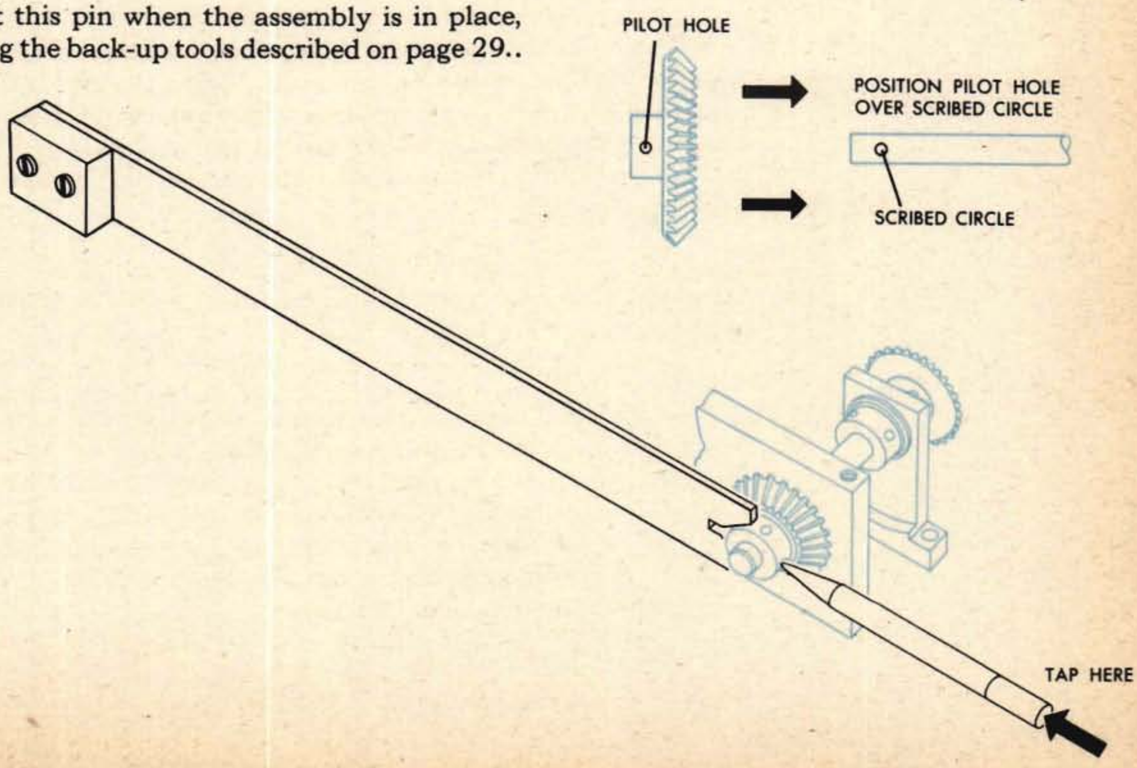
After the gear has been correctly positioned and held by a set screw, insert a thin scriber at a sharp angle through the pilot hole and scribe a circle on the shaft as large as the pilot hole. Then loosen the set screw, take off the gear, and remove the rest of the assembly from the instrument.

On the bench, remount the gear on the shaft and carefully align the pilot hole with the scribed circle on the shaft. Drill and ream the hole and insert the pin, but do not seat it until all the other parts have been pinned and the entire assembly remounted in the instrument.

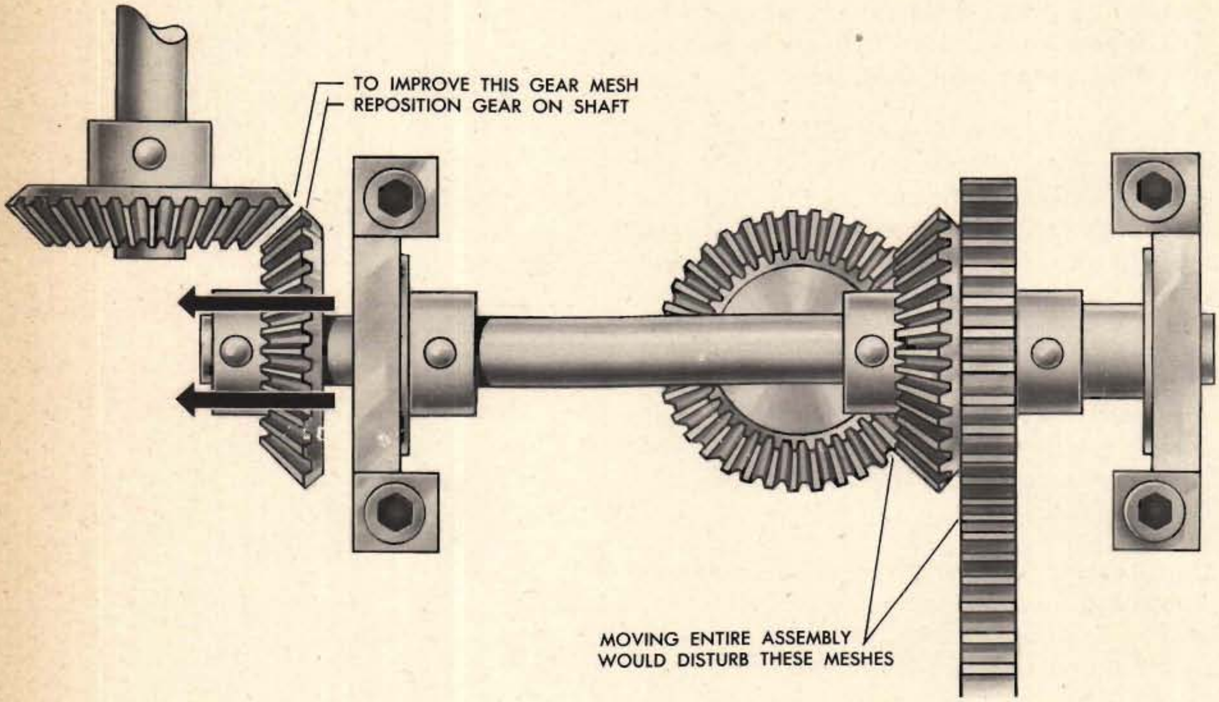
Seat this pin when the assembly is in place, using the back-up tools described on page 29..







Repositioning a gear on a shaft

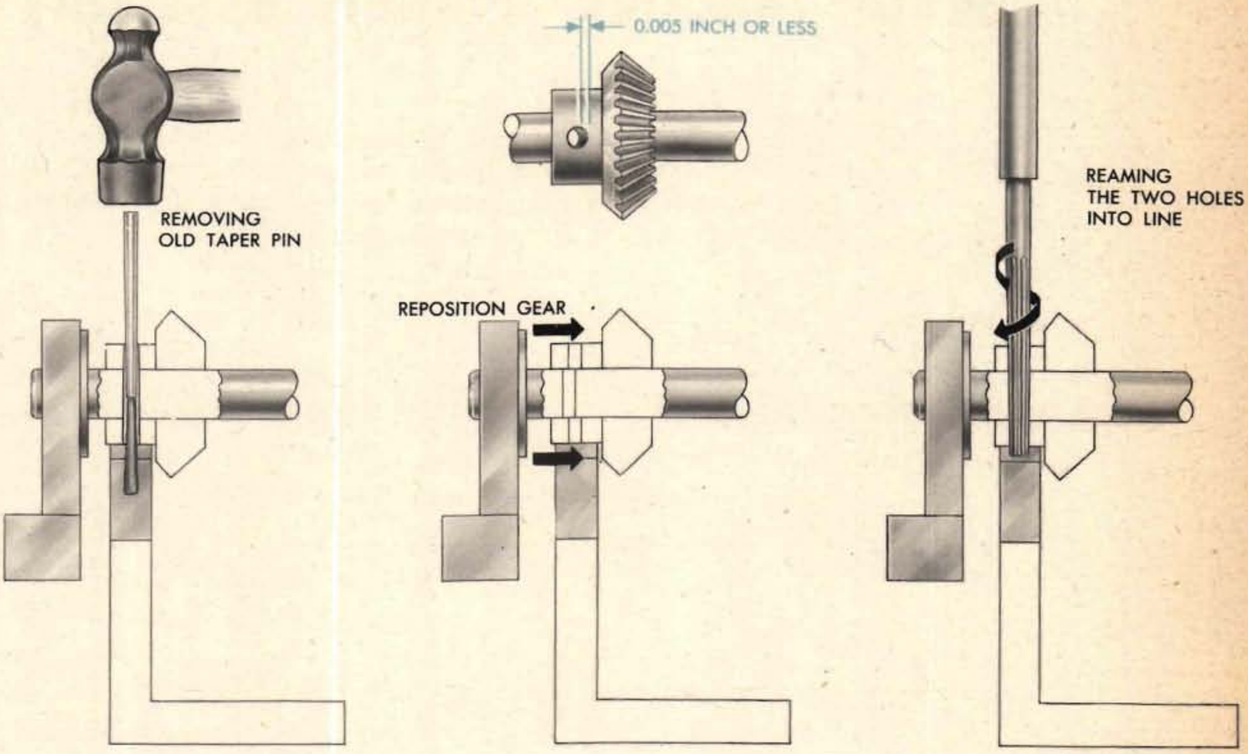


Sometimes the best method of repositioning a gear is to unpin the gear and move it into a new position. This operation is often necessary to obtain a correct bevel gear mesh on an assembly which has two or more bevel gears. If the whole assembly is moved to reposition one bevel gear, the other bevel gear meshes may be disturbed.

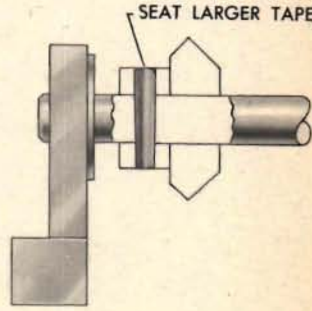
In relocating a gear to correct the mesh, it is best to use new parts if they are available.

If new parts are not available, an oversize taper pin must be used with either the old shaft or a new one. If the gear does not have to be moved more than 0.005 inch, the old shaft may be used. But if it must be moved more than 0.005 inch, a new shaft should be used. The use of oversize taper pins should be avoided, if possible, because it requires reaming a larger hole which will weaken the assembly.

Using the same shaft



First remove the taper pin by carefully tapping it out from the small end. After repositioning the gear, insert and tighten a set screw to hold the gear. Be sure to keep the large end of the hole in the hub over the large end of the hole in the shaft.



Hand-ream the two holes into line, seat an oversize taper pin, and stake it.

Check the shaft for run-out and *remove the set screw* before reinstalling the assembly.

Using a new shaft

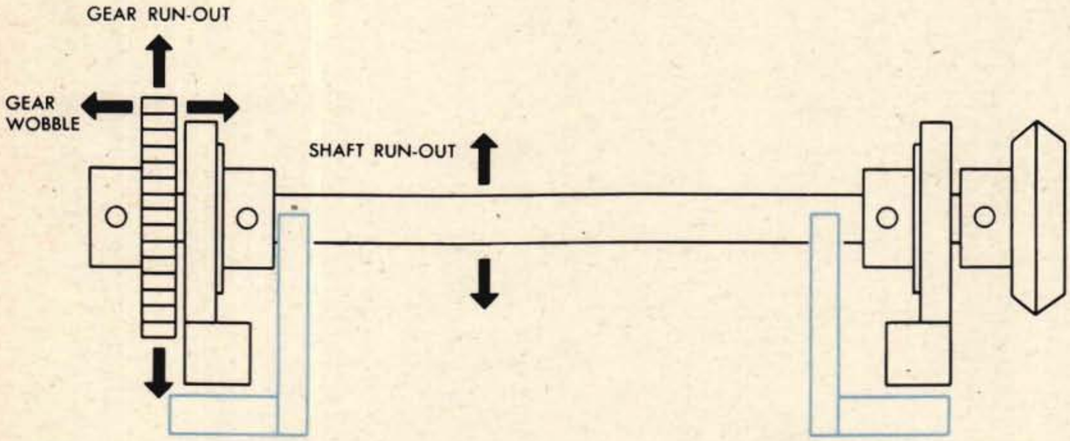
Fit the gear and other parts to the new shaft, and reinstall the assembly in the instrument to correct end play and lost motion. Position all the parts and hold them in place with set screws. Then remove the assembly for pinning.

When the same collar or hub is used, the simplest method is to drill an entirely new hole for the taper pin. Use a straight drill and a hand reamer as explained on page 63.

After pinning the parts, check the shaft for run-out and *remove all set screws* before reinstalling the assembly.

Bench checking a shaft assembly

Whenever a shaft assembly has been removed from an instrument for any repair, it should be checked for shaft run-out, and for gear run-out and side wobble. Gear run-out and side wobble are almost always caused by a bent shaft.



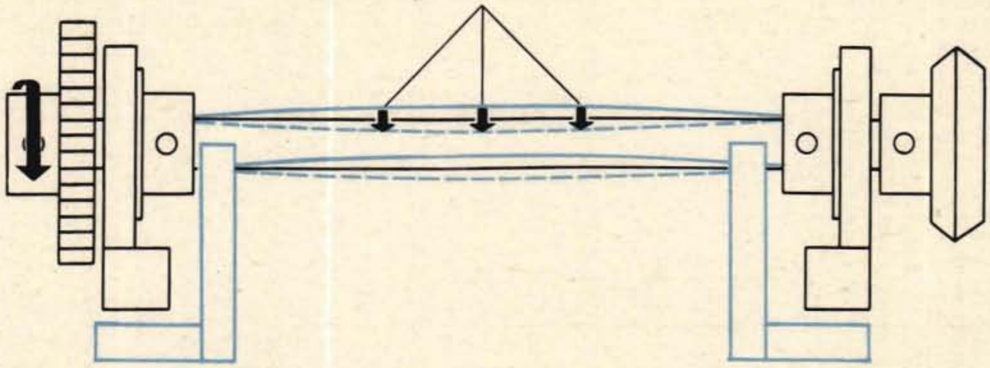
When any part has been newly pinned, checking the shaft for run-out is especially important.

Place the entire assembly on V rests or pinning supports on a bench plate. A dial indicator mounted on the plate alongside the assembly is used to make all measurements.

Shaft run-out

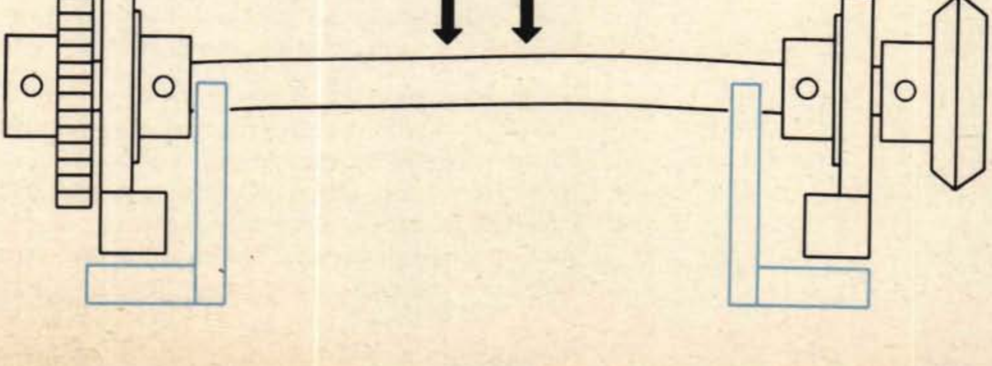
Mount the assembly with the V rests or pinning supports between the hangers, near the collars. Place the point of the dial indicator against the side of the shaft between the hangers and slowly turn the shaft. If the shaft runs out, the movement of the dial hand will indicate the exact amount. Repeat this check at several points on the shaft between the hangers.

CHECK SHAFT RUN-OUT



If a shaft does not run true within 0.002 inch total indicator reading at all points, it must be straightened. Strike the high points lightly with a plastic or soft-face hammer until the shaft is straight within this tolerance.

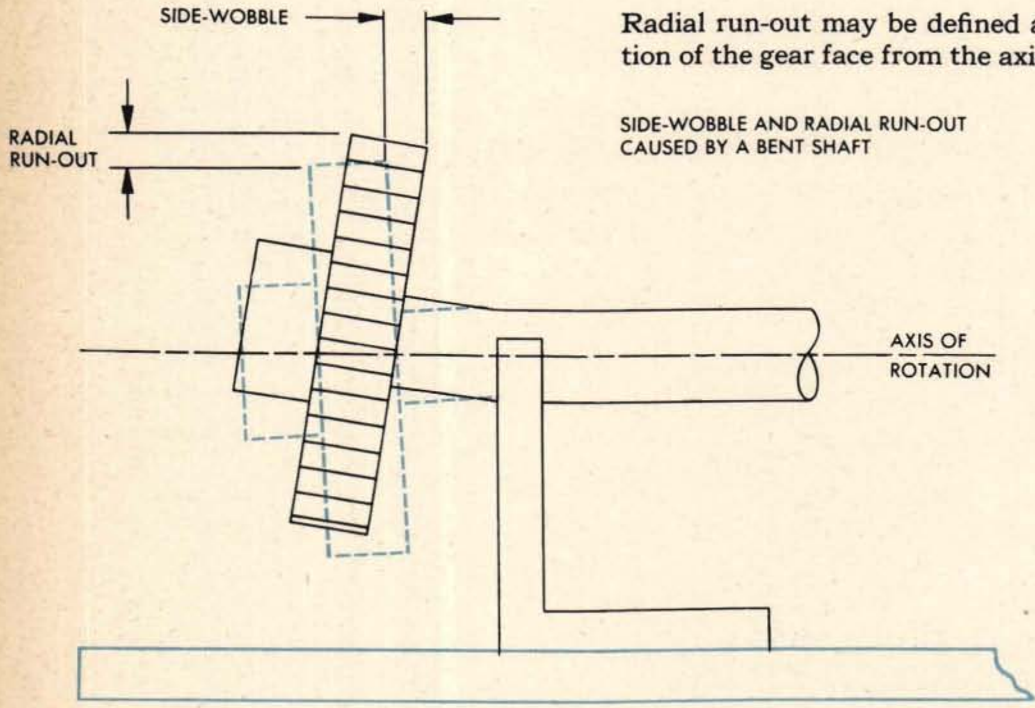
STRAIGHTENING A SHAFT



Gear side-wobble

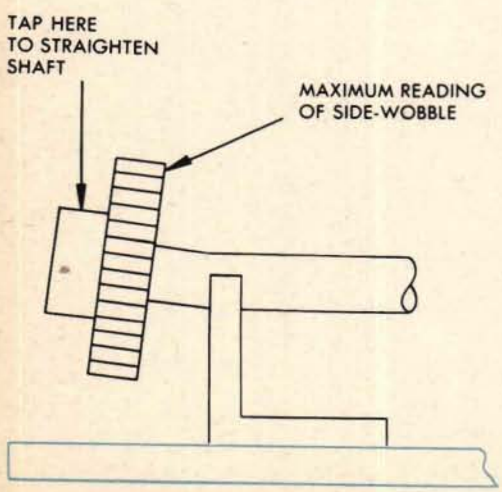
Side-wobble may be defined as the deviation of the side of a gear from a plane perpendicular to the axis of rotation.

Radial run-out may be defined as the deviation of the gear face from the axis of rotation.



SIDE-WOBBLE AND RADIAL RUN-OUT CAUSED BY A BENT SHAFT

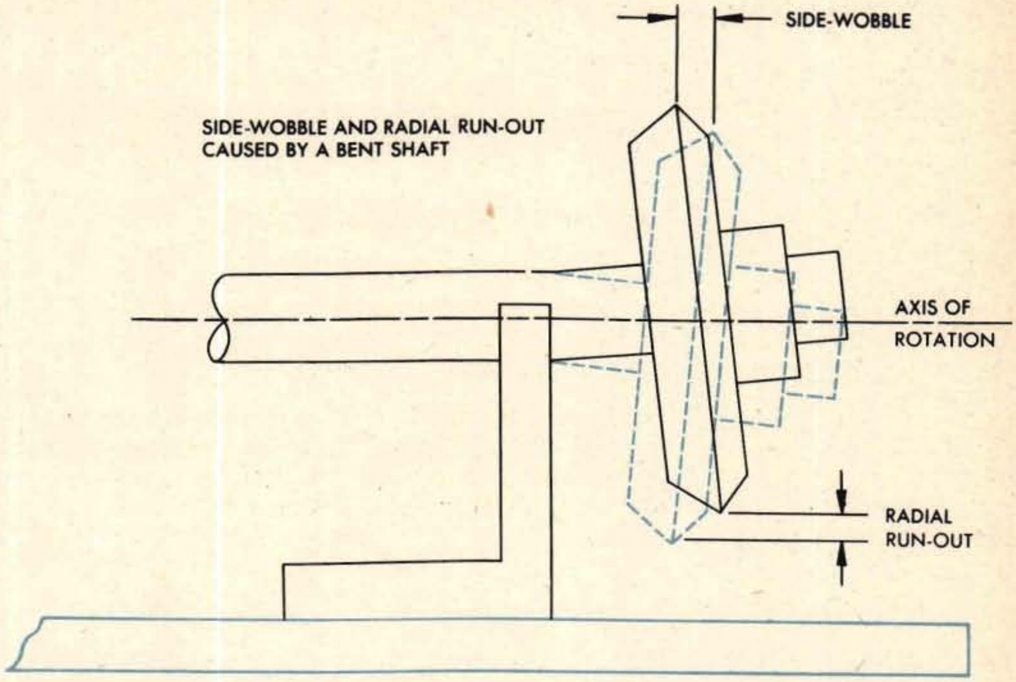
A bent shaft may cause side-wobble alone, or a combination of side-wobble and radial run-out in the same gear. Straightening the shaft to eliminate side-wobble will also eliminate radial run-out. For this reason, it is necessary to measure only side-wobble.



Radial run-out due to eccentricity need not be considered, because it is purely a manufacturing problem. If it exists after side-wobble has been eliminated, the parts of the assembly should be checked against the drawings.

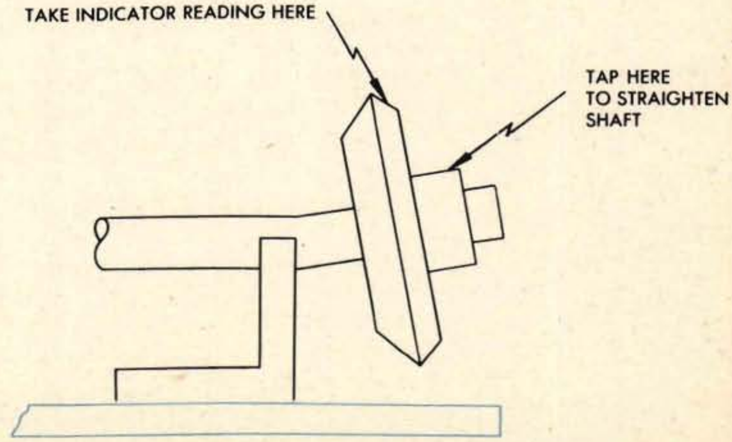
To measure side-wobble in a spur gear, place the point of the dial indicator on the side of the gear at the root of the teeth and turn the gear. The total indicator reading must not exceed 0.002 inch. If the reading is over 0.002 inch, straighten the shaft by tapping the gear hub until the gear runs true within this tolerance. CAUTION: Support the shaft in V blocks before hammering on it. Be careful not to damage the bearings.

Bevel gear run-out and side-wobble



Bevel gear side-wobble and run-out due to a bent shaft are measured simultaneously in one operation by placing the point of a dial indicator against the back of the gear at the root of the teeth and turning the gear.

Since the backs of bevel gears are cut at an angle, the total indicator reading represents a combination of side-wobble and run-out. If it exceeds 0.001 inch, straighten the shaft by tapping the gear hub until the gear runs true within this tolerance.



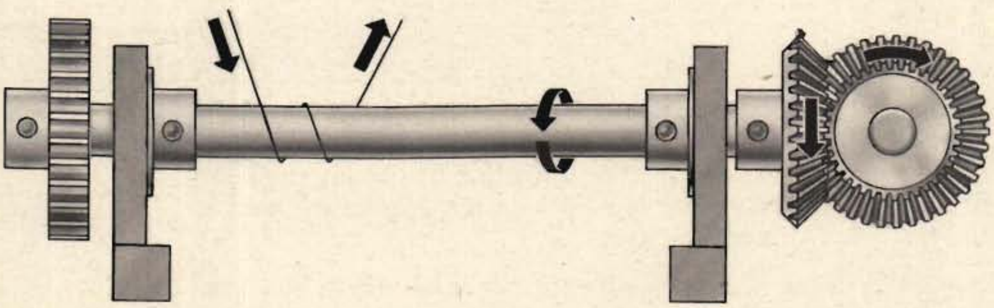
Final mounting of a shaft assembly

Locate the assembly on the plate over the screw holes. Insert the screws and tighten them enough to hold the assembly while it is checked in place.

Checking an assembly in place

Check the assembly for end play and for lost motion at the gear meshes. Obtain the correct position by loosening the screws and shifting the hangers toward or away from the meshing gears if necessary.

If there are tight spots in a mesh, inspect the gear teeth for burrs or nicks. If any are found, carefully remove them with a jeweler's file.



Running-in

Slight stickiness or roughness in a gear mesh can often be eliminated by lubricating and running the gears for a short time. The shaft may be turned by means of spinning cord wound several times around the shaft. Keep the cord near a bearing in order not to bend the shaft.

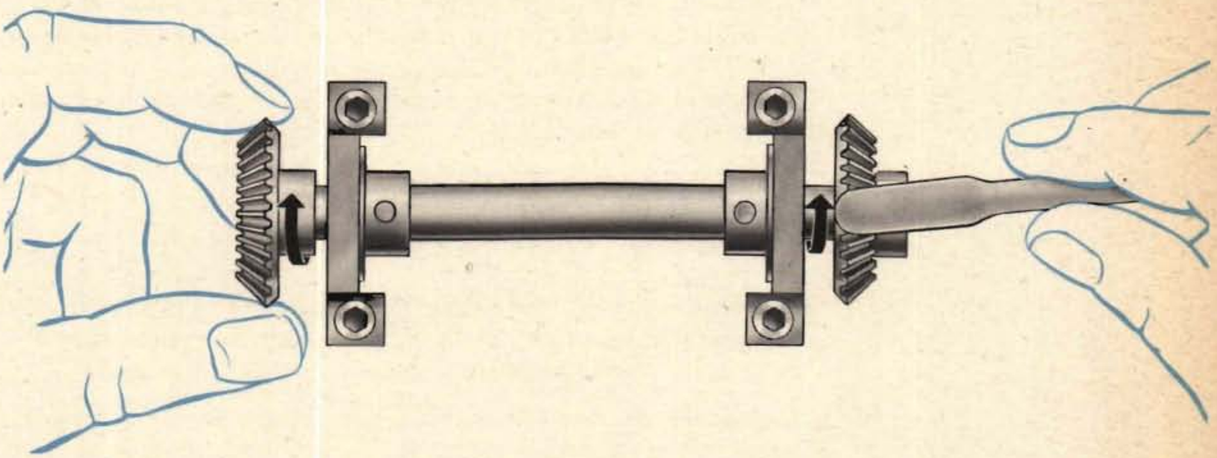
If running-in the gears with a lubricant does not make the mesh smooth enough, it may be necessary to use a running-in compound, but only as a last resort. Never use a commercial abrasive compound for running-in aluminum gears, however, because an abrasive hard enough to cut will become embedded in the aluminum. Embedded abrasive will wear the gear teeth excessively, and may eventually cause them to break off.

Making and applying running-in compound

The most suitable base for a running-in compound is rottenstone, but even the finest grade obtainable should be sifted through a 230-mesh screen.

To make a running-in compound suitable for use on instrument gears, mix light machine oil with the screened rottenstone to about the consistency of heavy cream.

Apply only a small amount, uniformly. Soft wood applicators or brushes with loose bristles should not be used because they may shed splinters or bristles in the compound.



This running-in or final fitting operation should be continued only long enough to obtain the desired smoothness of operation, and should be done slowly enough to prevent throwing the compound off into bearings or other mechanisms. As an added precaution, protect nearby mechanisms by covering them with tissue. Afterward, wash the shaft assembly thoroughly. Pay particular attention to cleaning the ball bearings.

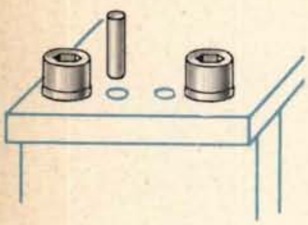
Washing and lubricating an assembly

After the final fitting is completed, wash the whole assembly thoroughly with a solvent equivalent to Navy Spec. 14K1 to remove all traces of compound and other foreign matter.

Finally, when the assembly is completely dry, lubricate all bearings and gears with a fine film of light oil.

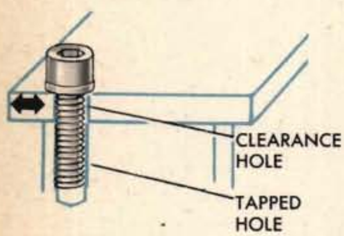
DOWELING

PARTS ARE POSITIONED BY DOWELS



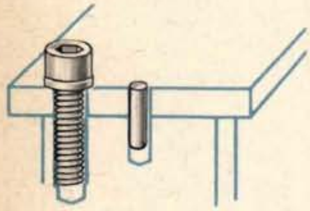
A dowel is a pin driven into matched holes in two parts of an assembly to hold them in position after they have been adjusted. Dowels eliminate shifting of screw-fastened parts and make it possible to reassemble them exactly in their original positions without further adjustment.

PARTS CAN SHIFT WHEN HELD BY SCREWS



In order to make screw-fastened parts easily interchangeable, clearance holes are drilled 0.005 to 0.010 inch larger than the outside diameter of the screws. Unless dowels are used to hold the parts in position, the parts may move through this clearance if they are subjected to a heavy load or shock, or if the screws become loose. This small movement is enough to bind gear meshes in an instrument.

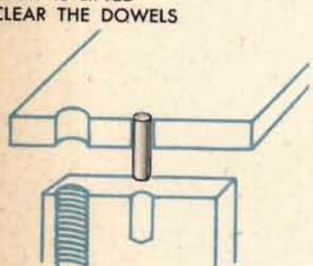
DOWELS PREVENT SHIFTING



Dowels should be fitted only *after the parts have been correctly aligned*. If it becomes necessary to re-align the parts after the dowels are fitted, the parts will have to be doweled again.

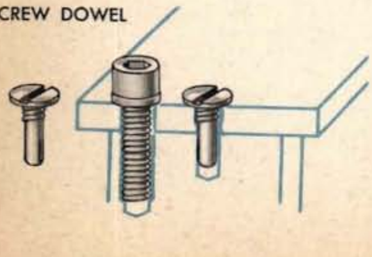
If dowels are not square with the parts they join, separating the parts will be extremely difficult. Therefore it is important in all doweling to drill every hole at right angles to the surfaces of the parts. Wherever possible, this should be done on a drill press.

THE PART IS LIFTED TO CLEAR THE DOWELS



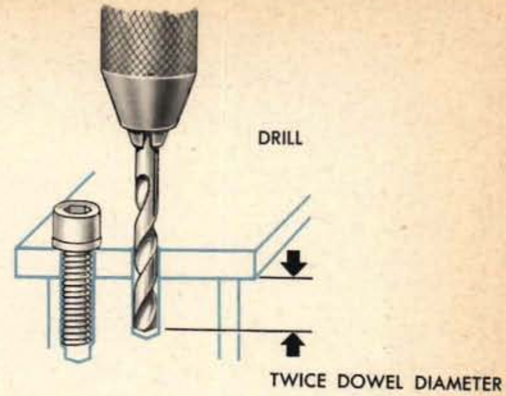
Dowel holes are drilled for a drive-fit in the smaller of the parts to be doweled, usually the one provided with screw clearance holes, and for a push-fit in the larger part. When the screws are removed and the parts separated, the dowels remain in the smaller part. To separate doweled parts, it is necessary to lift the smaller part straight up until the dowels clear the holes in the other part.

SCREW DOWEL



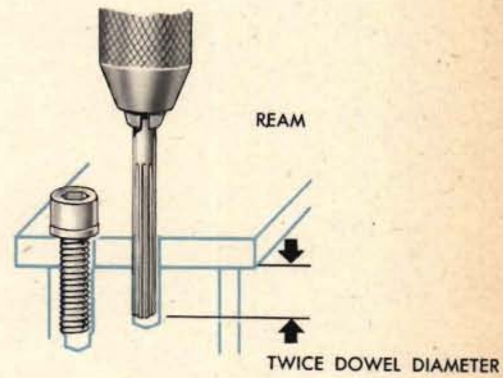
Where there is not enough space to lift a unit to clear the dowels, it is usually fastened with screws and held in position by *screw dowels*. Like other dowels, screw dowels are fitted only after the parts have been correctly aligned.

When the dowel holes are provided in one of the parts to be joined, they are used to guide the drill in making the matching holes in the other part. To make the new holes straight and to avoid enlarging the prepared hole, the drill must be held exactly perpendicular to the surface.

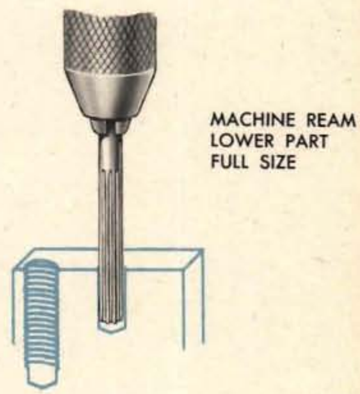


Dip the drill in grease to lubricate it and to make it retain chips. Drill each new hole to a depth twice the diameter of the dowel to be used in it.

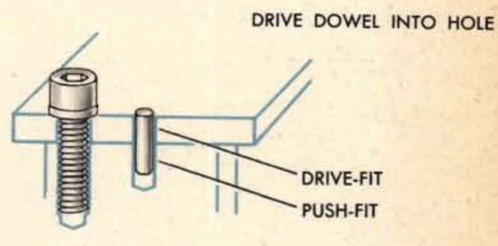
With an undersize reamer, ream through both parts to the bottom of the new hole. This operation will make a drive-fit in both parts, or a permanent fit.



Where the parts may have to be separated later, always remove the upper part and ream the lower part for a push-fit with a full-size reamer.

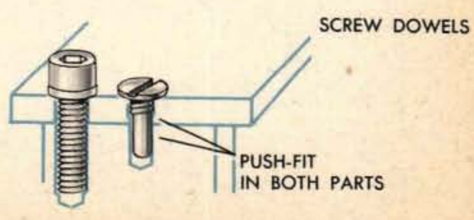


Grease the dowels before driving them.



Screw-dowel holes are reamed for a push-fit in both parts to allow the dowel to turn easily.

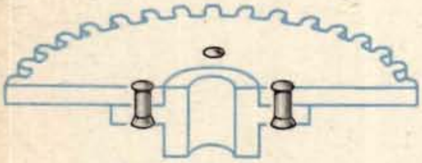
To redowel parts, remove the old dowels and fit larger ones, or drill a new dowel hole near the old one.



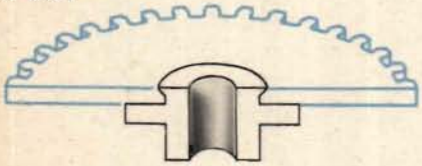
RIVETING

Riveting is a means of fastening two or more parts of an assembly together by forming or peening metal. Rivets may be used, or one of the parts may serve as a rivet in addition to its other functions in the assembly. Here are illustrations of both types of riveted assembly.

WHERE RIVETS ARE USED



WHERE ONE OF THE PARTS SERVES AS A RIVET



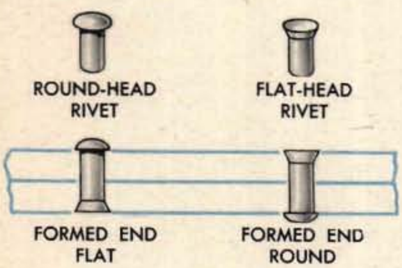
In the first, rivets have been fitted in matched holes drilled through a gear and the flange of a gear hub.

In the other type, a lip on a hub has been peened over into a countersink in a gear.

Instructions for both methods of riveting follow. When either method is used, the parts must be held tightly together during the operation to prevent spreading them. To avoid bending a part, it is necessary to provide support directly under the work, where the force of the hammer blows is concentrated. No hammer blow should ever strike a finished surface.

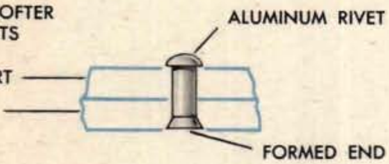
Where rivets are used

RIVET ENDS



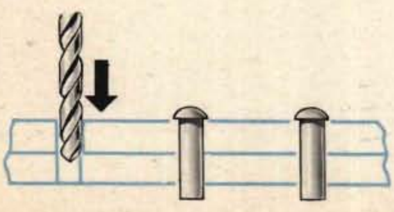
The most commonly used rivets are the *round-head* and *flat-head* types. A *round end* or a *flat end* can be formed on either type of rivet.

THE RIVET IS SOFTER THAN THE PARTS



All rivets used in an instrument are of soft steel or aluminum, and they are worked cold. When two parts of different materials are to be riveted together, the head of the rivet is formed against the harder of the two parts.

ALIGNING RIVET HOLES

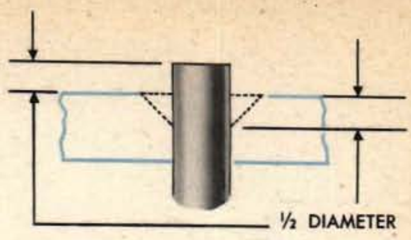


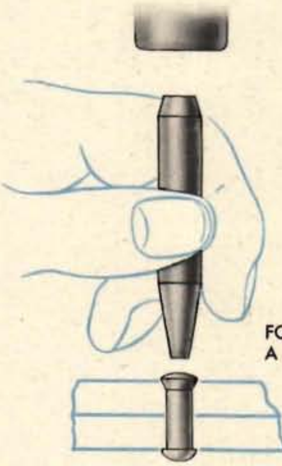
To prevent shifting of the clamped parts during riveting, always insert all the rivets before starting to form the ends. Be sure that all of them fit snugly in the holes, but never force a rivet into a hole, because forcing it may spread the parts. If any of the holes are out of line, use a drill of the proper size in a hand-chuck to align them.

The depth of the countersink in which a flat end is formed should be about half the diameter of the rivet. Select a rivet which projects above the surface of the part to a height equal to the depth of the countersink.

Form the end by light blows with a flat-point punch and a hammer. Many light blows will form a better rivet end than a few heavy blows. After the end is evenly formed in the countersink, file the excess material until the rivet is flush with the surface of the part.

Form a round end above the surface of the part by using a cup-point punch instead of a flat-point punch.

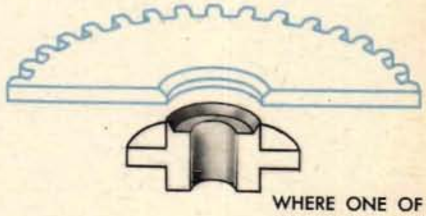




FORMING
A FLAT END

Where one of the parts serves as a rivet

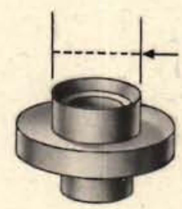
The parts are specially prepared when one of them serves as a rivet. One part is provided with a raised lip to be peened over into a prepared countersink in the other. The part which is peened over resembles a flat-end rivet in this respect.



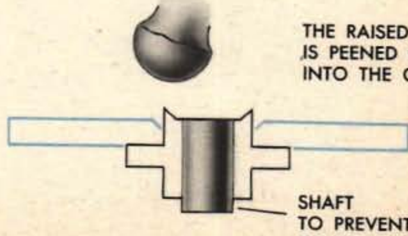
WHERE ONE OF THE PARTS
SERVES AS A RIVET

The instructions on assembly drawings sometimes refer to this operation as spinning. Spinning requires power machinery and special fixtures to force the lip into the countersink with pressure rollers. But any part made for spinning can be peened by hand on the bench with a hammer. Where one part drives another, as in a hub-and-gear assembly, dowels must be fitted to prevent slipping of the parts.

Before peening the lip over, measure the diameter of that part of the hub which fits into the gear. On the next page instructions are given for making a special jig to center the dowel holes on this diameter.

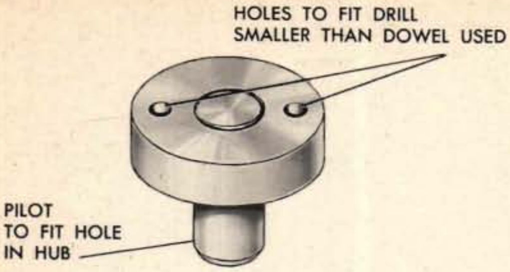


While peening the lip over, keep a short length of shaft in the hole to prevent distortion of the hub. Peen the raised lip over into the countersink as uniformly as possible by tapping very lightly all around the edge.

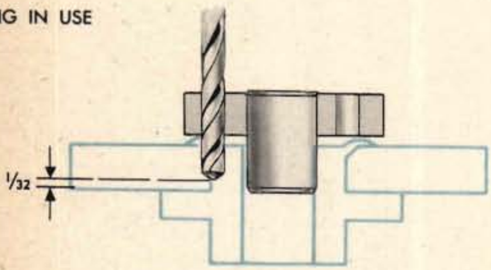


Now dowel holes must be drilled.

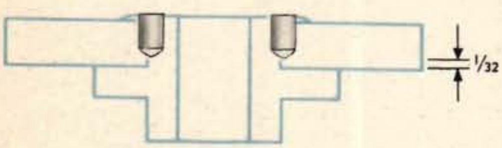
A JIG



THE JIG IN USE



DOWELS IN POSITION



The two dowel holes must be drilled half in the hub and half in the gear to prevent slipping. A special jig to fit each assembly must be made to center these holes accurately and to keep the drill from walking away from the harder of the two metals.

Model the jig on the drawing shown here. It consists of a drill plate and a pilot which fits into the hub hole to center the jig on the assembly.

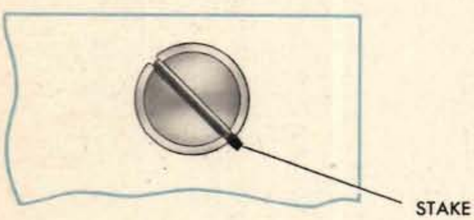
On the drill plate, center the holes the same distance apart as the previously measured diameter of the hub where it fits into the gear. Drill these holes slightly smaller than the dowels to be used.

Using the jig, drill two holes in the hub-and-gear assembly to a depth 1/32 inch less than the gear thickness. Finally, drive two dowels in the holes and stake them with a center punch.

Riveting and positioning eccentric roller studs

A RIVETED ECCENTRIC STUD

THE STUD IS STAKED



This operation is a variation of riveting where one of the parts serves as a rivet.

Fit the stud in the hole. If necessary, ream the hole for a tight push-fit. Before peening the lip, remove the stud and grease it.

Tapping lightly with a hammer, peen the lip evenly and turn it occasionally until it is fairly hard to turn. The stud and the part will now hold together, but the stud can still be positioned.

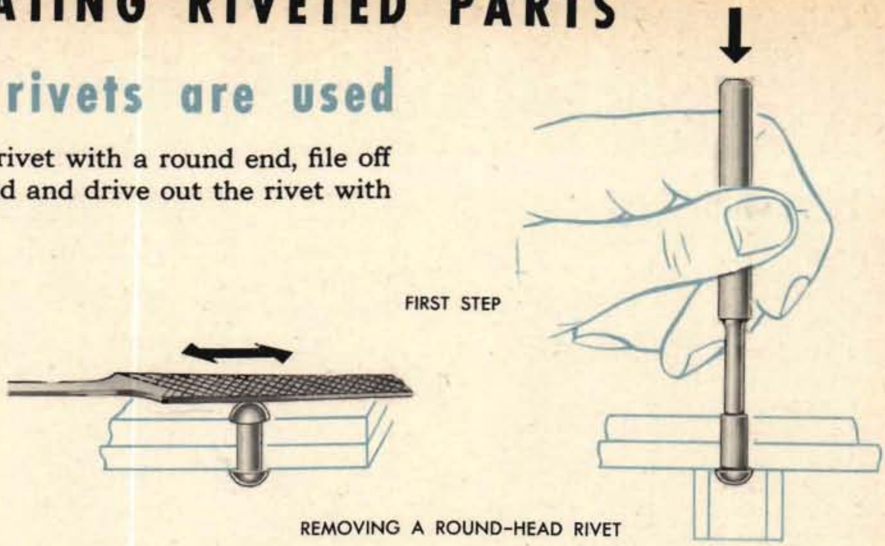
To position the stud, insert a screwdriver in the slot and turn the stud to the correct position.

After this final adjustment, lock the stud by staking or forcing metal into one end of the slot with a center punch.

SEPARATING RIVETED PARTS

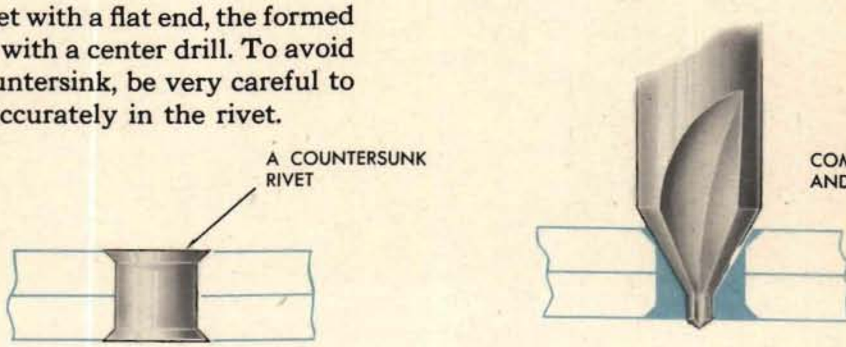
Where rivets are used

To remove a rivet with a round end, file off the formed end and drive out the rivet with a punch.



REMOVING A ROUND-HEAD RIVET

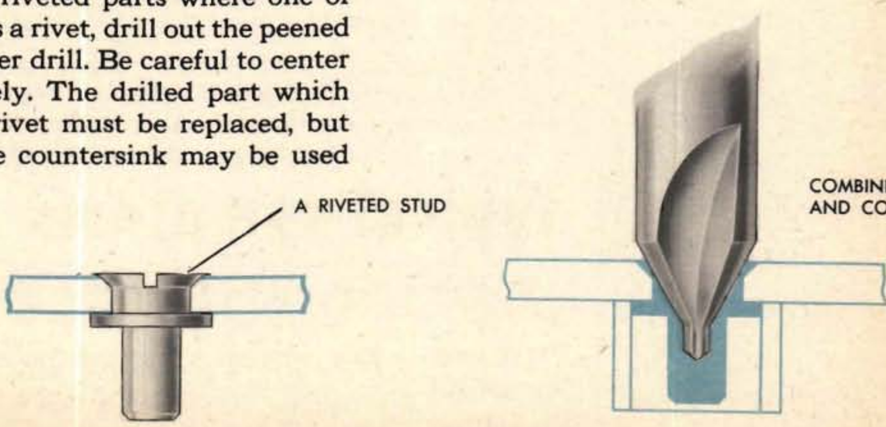
In removing a rivet with a flat end, the formed end is drilled out with a center drill. To avoid damaging the countersink, be very careful to center the drill accurately in the rivet.



DRILLING OUT A COUNTERSUNK RIVET

Where one of the parts serves as a rivet

To separate two riveted parts where one of the parts serves as a rivet, drill out the peened metal with a center drill. Be careful to center the drill accurately. The drilled part which has served as a rivet must be replaced, but the part with the countersink may be used again.



DRILLING OUT A STUD